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APPLIED MECHANICS REVIEWS

OL. 8, NO. 12 | MARTIN GOLAND *Editor* | DECEMBER 1955

A SURVEY OF SOME RECENT DEVELOPMENTS IN THE AUTOMATIC CONTROL FIELD

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INTRODUCTION

THE rapid growth of the use of automatic controls and the expanding application of feedback concepts to diverse areas of endeavor have produced an ever-increasing flow of published material. Since no single paper can hope to present all of the significant advances, the author has restricted his effort to a selected few developments which he considers to be of importance, which are in a relatively immature state, and which have not as yet been fully documented in the professional literature. The discussion of such developments is preceded by a very brief presentation of the general subject.

A major effort has gone into the formulation of techniques for the analysis of the system shown in Fig. 1.

A system (the plant) has an output, c, whose change in value is a function of the disturbances (m_L) and the manipulated input (m). It is required that a second system (the controller) be designed to insure that the output c follow the reference input (r) with an error ($r - c$) which always falls within specified limits. While in actual practice nearly all such systems exhibit some nonlinearities, it is conventional to make assumptions which permit the use of linear analysis techniques. In many instances the final design is checked by a more faithful representation of the actual system.

The error (ϵ) as a function of time is given by Equation [1].

$$\epsilon = \frac{r - h_L m_L}{1 + hg} \qquad [1]$$

h_L, h, and g are operators defined by Equations [2], [3], and [4].

$$h_L m_L = c_{m=0} \qquad [2]$$

$$hm = c_{m_L=0} \qquad [3]$$

$$g\epsilon = m \qquad [4]$$

Much of the research-development effort has been concerned with high performance servos driving a plant consisting essentially of an inertia load. In such instances, nature of the plant behavior described by h could readily be determined by the application of Newton's laws. System parameters, moment of inertia, and damping ratio were in general known. The task was to design the controller whose output-input behavior is described by the transfer characteristic g such that: (1) the over-all system would be stable; (2) its response to changes in the reference input r and its recovery from load disturbances m_L would be fast; (3) the steady-state errors resulting from input changes would be small.

The general procedure which has developed is to subject a proposed system to reference input disturbances and to compute the dynamic response for a relatively wide range of plant and controller parameters. Input disturbances used are of the following character. *Transient response:* (1) Step change in r. (2) Pulse change in r. (3) Random variation in r. *Steady-state response:* (1) Sinusoidal variation in r.

A large and rapidly growing literature exists devoted to the use of frequency-response techniques. In dealing with linear systems of relatively low order, the ability to get steady-state sinusoidal responses analytically without the determination of the roots of the differential equation makes it possible to get solutions fast. In addition, the use of simple graphical methods, many of them involving logarithmic scales, have permitted the rapid design of suitable systems. Variable as such methods of analysis are and will continue to be, the expected return from future efforts in the same direction appears to be small. It should also be pointed out that while the development of the use of the describing function technique has permitted the application of frequency response techniques to certain relatively simple nonlinear systems, the method is basically applicable to the analysis of linear system on systems where simple linear approximations can be made validly.

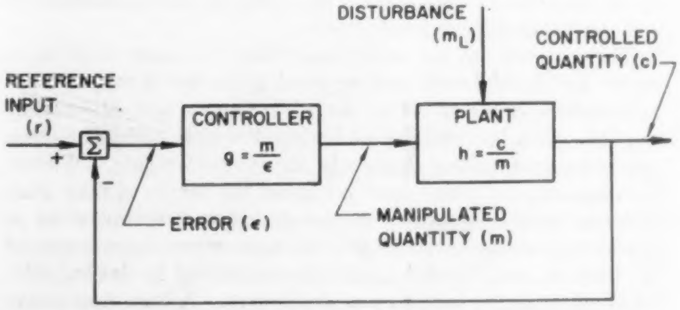

Fig. 1 Block diagram of feedback control system

An increasing number of engineering control problems are concerned with complex systems, often containing many loops and almost invariably having numerous nonlinear elements. It is important to give serious consideration to including in the controller design nonlinearities in addition to those which often occur unavoidably. Here, real advantages accrue from carrying out solutions in the time domain.

While some progress has been made in the solution of high-order differential equations to speed up the time of solution (e.g., root locus, graphical methods, etc.), the present situation is far from one which permits adequate design of a complex system in a reasonable time period. However, the status of the rapidly developing computing machine field is now such that very difficult systems can be rapidly represented in a form to feed into either analog or digital computing machines, wide parameter ranges can be explored, nonlinearities can be included. A large number of time solutions can be rapidly obtained.

Since many control problems are represented by sets of differential equations, the fast analog computer for a given investment is the most satisfactory. This is particularly true in the many instances where rapidity of solution and flexibility to rapidly change the setup with adequate but not extreme accuracy are required. One would predicate that in the near future a judicial selection of both digital and analog techniques will give greater scope and convenience to machine methods of computation.

The existence of good machine computing capability has taken the pressure off the development of classical approaches to the solution of dynamics problems in general. This does not mean that such work is not valuable. Its greatest value to the engineering profession will be that a greater understanding of how to handle difficult equations will permit more intelligent use of computing machines. The ability to solve readily very complex sets of equations, coupled with the growing pressure to apply feedback control to a wide variety of complicated situations, places an enormous importance upon adequate knowledge concerning system behavior.

It is important to be able to state with required accuracy the transfer characteristics (output-input relations) for many different processes and systems. Because much of this information is unknown and because suitable formulation in many cases cannot be made without measurements of dynamic performance on the actual system or a prototype thereof, methods for making and utilizing such measurements are extremely important. Such information has been obtained by applying known input or load disturbances and measuring the changes in output. The character of the disturbances applied have been largely in two categories: step and pulse disturbances of known magnitude, or sinusoidally varying disturbances of known amplitude and frequency. In the first case the transient response is measured. In the second case the steady-state output (amplitude and phase) is measured. Both types of disturbances are often difficult to apply and, in cases where a useful product is being made, are often objectionable. The frequency response data are of value only for linear operation of the system. Nevertheless, such measurements are now being made in great numbers.

The objections to the techniques referred to above have led to active and fruitful work making possible the use of output-input information obtained when no disturbances are deliberately applied. Random variations in input which normally occur produce corresponding changes in the system outputs. Wiener, Lee, Booton, and others have published the results of their work utilizing such information in the design and optimization of closed loop control systems. Until some recent work reported by Reswick and Goodman, the labor involved in dealing with relatively complex systems was prohibitive. A brief description of the work of Reswick and Goodman follows.

As previously pointed out, there are very significant advantages to the determination of system characteristics from normal operating records. In the work referred to, simultaneous records of output and input are taken over a period of time. From such records the auto and cross-correlation functions[1] are determined.

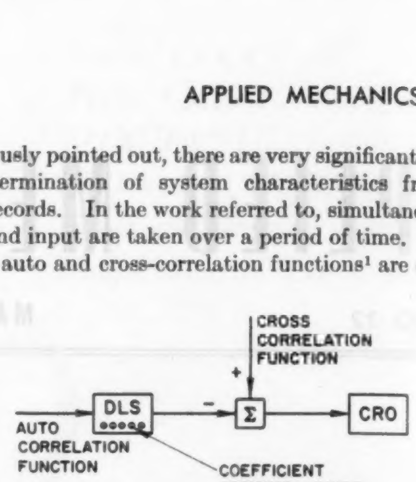

Fig. 2 Utilization of delay line synthesizer to determine weighting function of a system

This information is then used, as indicated in Fig. 2, to determine the weighting function (impulse response) of the system. The autocorrelation function is introduced as an input to a unit called The Delay Line Synthesizer (DLS). The output of the DLS is directed to a summing box where it is subtracted from the measured cross-correlation function. The output of the summing box is displayed on a cathode-ray oscilloscope. The DLS settings are adjusted to produce a zero signal on the oscilloscope. Under this condition the output of the DLS is identical with the measured cross-correlation function. Therefore the DLS is an analog of the system from which the measured data were obtained. If now a pulse is applied to the DLS, the output of the DLS will be the weighting function of the system. The application of sinusoidal inputs will yield frequency-response information. The method is fast and applicable to many control applications, particularly to those which are often difficult to control. A brief description of the equipment used is in order.

The Delay Line Synthesizer is a device consisting of a large number of delay units connected in series. Ideally each delay unit operates on its input to produce an output which is delayed in time but otherwise undistorted. See Fig. 3. The output of each delay unit is tapped, and any fractional amplitude of the input signal, either positive or negative, is sent to a summing element where the tapped outputs of all delay units are summed to give the output of the DLS. See Fig. 4. If the attenuation and sign designation of the delay unit outputs are represented by the operator, h, then the relation of the output of the DLS, $c(t)$, to the input, $m(t)$, is given by

$$c(t) = h_0m(t) + h_1m(t - T) + h_2m(t - 2T) + - - - -h_km(t - kT)$$

or

$$c(t) = \sum_{n=0}^{k} h_k m(t - nT) \qquad [5]$$

where T = the time delay of each delay unit
t = time

The coefficients h are given directly by the settings of the dials on the DLS. Equation [5] suggests the direct use of input-output-time data for the determination of the system characteristics which are known if the appropriate values of h can be found. Because of the nature of the normal operating records of many regulated processes, the direct use of this information often leads to a difficulty in operating the knobs of the DLS to produce a zero signal on the oscilloscope shown in Fig. 2.

[1] The words "auto and cross-correlation" are used advisedly, since the limited data from which the functions are computed are not usually "stationary." It is necessary only that identical operations be performed when forming each function.

This difficulty is due largely to the fact that the influence of many of the delay unit outputs upon the over-all DLS output $c(t)$ is widely distributed in time.

It can be shown that the cross and autocorrelation functions of the system are related in precisely the same manner as the output-input data are

$$\phi_{mc}(\tau) = \sum_{0}^{k} h_k \phi_{mm}(\tau - nT) \qquad [6]$$

Noise which does not enter the system as a part of the input $m(t)$ is not correlated with $m(t)$ and hence contributes nothing to the cross-correlation function. Thus, the solution of Equation [6] is usually more easily obtained than the solution to Equation [5]. The effective use of the DLS is greatly enhanced by the fact that the autocorrelation function always exhibits a central peak and approaches zero in both positive and negative time directions. Hence, the use of the (ϕ_{mm}), the autocorrelation function, as an input is akin to the application of a pulse input to the system. Such an input causes the influence of each delay unit on the system output to be localized in character and makes a determination of the values of h_n rapid. It is interesting to note that this approach is effective in dealing with closed loop

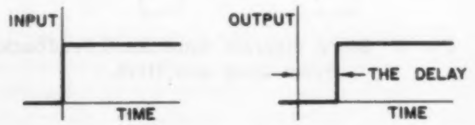

Fig. 3 Operation of delay line synthesizer–step input

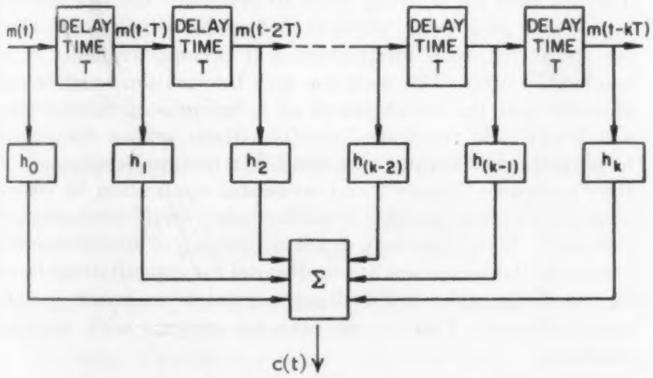

Fig. 4 Block diagram of delay line synthesizer

systems subjected to noise disturbances, a situation where previously established techniques have been relatively unsuccessful.

The construction of a dual function generator is now well along. All of the equipment is designed for coupling to general-purpose fast analog computing units. Results reported to date on data from operating systems are excellent. The approach should be of great help in making available much needed information on the dynamic behavior of many processes and systems.

The analysis and design of feedback control systems as just described are based upon a study of the system response to changes in reference input. Changes in output due to change in load and other disturbances are operated upon in the feedback path in identical manner. Such a design is open to serious question. In the absence of disturbances applied to the system, when the transfer characteristic of the plant is known and unchanging with time, no feedback is required to make the output follow changes in the reference input. The feedback requirement is imposed by the presence of input changes to the plant and changes in plant characteristics which cannot be known in advance. Concepts of feedback system design based on this line of reasoning have recently appeared in the literature.

Reswick, using the designation "disturbance response feed-

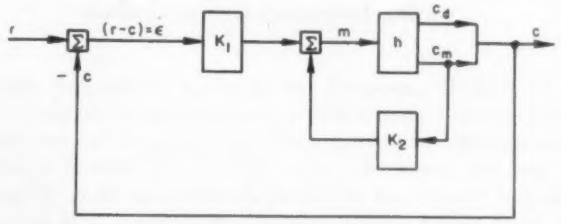

Fig. 5 Disturbance response feedback system

back," presents the following concept. Referring to Fig. 5, the plant is shown with the manipulated input m. All other inputs are assumed to be random in nature. The output to be controlled "c" can be thought of as the sum of the quantities "c_m" and "c_d," where c_m is the response of c to changes in the input m, and c_d is the response of c to changes in all other inputs to the system which is assumed to be linear. c_m is fed back positively through the gain K_2 around the plant; c is fed back negatively and combined in a summing element with the reference input. The result after passing through a gain K_1 is added to K_2c_m to form the manipulated plant input m. The performance of this system is described by the following relationships.

$$c = \frac{K_1hr + (1 - K_2h)c_d}{1 + (K_1 - K_2)h} \qquad [7]$$

$$\epsilon = \frac{(1 - K_2h)(r - c_d)}{1 + (K_1 - K_2)h} \qquad [8]$$

To obtain zero steady-state error, the following condition must be met.

$$(K_2h)_{ss} = 1 \qquad [9]$$

If

$$K_1 = K_2$$

then

$$c = K_1hr \qquad [10]$$

Thus the output of the plant c follows the reference input in accordance with the open loop transfer characteristic K_1h. Feedback is not used. However, when disturbances are imposed producing changes in c_d, feedback operates as indicated below.

$$c = -\epsilon = (1 - K_2h)c_d \qquad [11]$$

An application of the above philosophy illustrates the rather dramatic results obtainable. Assume that the plant is characterized by pure delay.

$$c_m = [e^{-\tau D}]m \qquad [12]$$

$$(K_2h)_{ss} = 1 \qquad [13]$$

$$K_1 = K_2 = 1 \qquad [14]$$

Consider the response of c to a step change in r.

$$\epsilon = 1 - e^{-\tau D} \qquad [15]$$

It will be noted that the error is reduced to zero in a time interval equal to the plant delay "T" without overshoot or oscillation. It is difficult to visualize more optimum behavior. See Fig. 6.

If c_m, the portion of the output produced by changes in m,

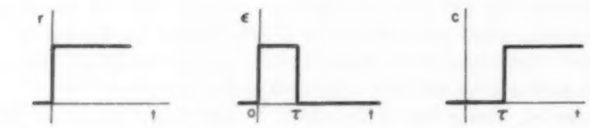

Fig. 6 Response of system consisting of pure delay plant employing disturbance feedback control

can be directly measured, the plant acts as its own regulator. Such a control system would represent a form of the much sought self-adjusting controller in which the plant and its controller are one and the same. In many instances c_m cannot readily be separated from c and no direct measurement of c_m is possible. The plant model controller as shown in Fig. 7 will accomplish the same result.

Independently Lang and Ham have presented a concept that they term "conditional feedback" which is aimed at providing individual means of handling changes in inputs and load changes. The system which they propose is shown in Fig. 8. The reference signal r is fed to the summing box through parallel paths containing the elements A and BG_2. The net signal appearing as an output of the summing box is zero, providing the system is designed as indicated below:

$$\left.\begin{aligned} (AHG_1)r &= Br \\ G_1 &= 1 \\ AH &= B \end{aligned}\right\} \qquad [16]$$

Therefore, if the above conditions are met, the response of the output of the plant c to reference input disturbances is given by

$$c = (AH)r \qquad [17]$$

There is no net feedback action. However, if disturbances c_d exist, the response of both the plant output c and the error are shown below (when $r = 0$)

$$c = \left(\frac{1}{(1 + HG_2)}\right) c_d \qquad [18]$$

$$\epsilon = -\left(\frac{1}{1 + HG_2}\right) c_d \qquad [19]$$

Feedback is used where needed in handling load changes. Performance well above that secured by conventional means is attainable. It will be noted that to fulfill the condition stated in Equation [16], the element B must include a model of the system, or the element A must include a model of transfer characteristic $1/H$.

These concepts appear to open the way for the design of systems quite different in character than those based on conventional approaches. In this connection it should be noted that in the case of "disturbance response feedback" the criterion for optimum performance is completely defined, for it is inherent in the design procedure.

As indicated at the outset, this discussion has been highly selective omitting completely a mention of important current work (e.g., the effort being devoted to the analysis and design of sampled-data control systems and the major effort in the field of information theory which is closely related to the control problem.) However, in closing, it is important to state one's very strong impression that, fertile as the field for the development of analysis and design techniques is, lack of knowledge of this type is not at present a barrier to the widespread application of control principles to a variety of complex situations in industrial and economic areas. The great barrier is the lack of knowledge concerning the transfer characteristics of many systems. There is need for a strong drive to determine the dynamic behavior of a great many physical and economic systems. There are signs that such information will become available at an accelerated rate. The need for such information must be emphasized and the development of techniques of measurement which will yield the desired results without serious disturbance to normal operation must continue. A mature development of the "automatic factory" and successful application of control concepts to other complex situations must await information of this kind. If the open loop dynamic behavior of system elements is known, the means are at our disposal for computations necessary to design successful feedback control of extremely complicated systems. This is true even for systems with nonlinear elements.

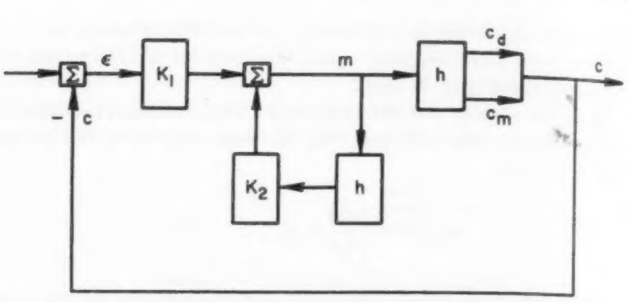

Fig. 7 Disturbance response feedback system using plant model

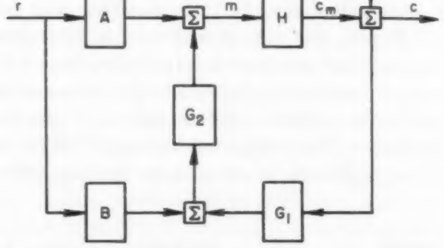

Fig. 8 Block diagram conditional feedback. (From Lang and Ham.)

REFERENCES

Truxal, J. G., Automatic feedback control system synthesis, New York, McGraw-Hill Book Co., Inc., 1955, xiii + 675 pp.

Evans, W. R., Control system dynamics, New York, McGraw-Hill Book Co., Inc., 1954.

Kochenburger, R. J., A frequency response method for analyzing and synthesizing contactor servomechanisms, *Trans. AIEE* 69, pp. 270–284, 1950.

Wiener, N., The extrapolation, interpolation, and smoothing of stationary time series, New York, John Wiley and Sons, 1948.

Application of statistical methods to communication problems, *M.I.T. Research Laboratory of Electronics Tech. Rep.* 181, 1950.

Booten, R. C., Non-linear systems with statistical inputs, *M.I.T. Dynamic Analysis and Control Laboratories Rep.* 61, 1952.

Goodman, T. P., and Reswick, J. B., Determination of system characteristics from normal operating records, ASME Pap. 55—IRD-1.

Reswick, J. B., Disturbance response feedback—a new control concept, ASME Pap. 55—IRD-2.

Lang, G., and Ham, J. M., Conditional feedback systems—a new approach to feedback control, *Trans. AIEE*, 1955.

Tustin, A., The mechanism of economic systems, Cambridge, Mass., Harvard University Press, 1953.

Books Received for Review

Fung, Y. C., An introduction to the theory of aeroelasticity, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1955, ix + 490 pp. $10.50.

Guerrin, A., Traité de béton armé, Vol. III, Les Fondations, Paris, Dunod, 1955, ix + 315 pp.

Heine, R. W., and Rosenthal, P. C., Principles of metal casting, New York, Toronto, London, McGraw-Hill Book Co., Inc., 1955, ix + 639 pp. $7.50.

Locke, W. N., and Booth, A. D., edited by, Machine translation of languages, Cambridge, The Technology Press of Massachusetts Institute of Technology; New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1955, xii + 243 pp. $6.

Truxal, J. G., Automatic feedback control system synthesis, New York, Toronto, London, McGraw-Hill Book Co., Inc., 1955, viii + 675 pp. $12.50.

Letters to the Editor

3590. Re AMR 8, Rev. 1677 (June 1955): A. W. Huber and L. S. Beedle, Residual stress and the compressive strength of steel.

The authors appreciate the comments made by Mr. Garofalo. It is considered that one of the important results of the paper was the demonstration of the lowering of axial column strength due to residual stresses. It was also shown that column strength depends on the axis of bending when residual stresses are present. For the same slenderness ratio, a WF column free to bend in the weak direction will have a significantly lower ultimate strength than one free to bend in the strong direction.

A. W. Huber, USA
L. S. Beedle, USA

Theoretical and Experimental Methods

(See also Revs. 3611, 3612, 3619, 3620, 3625, 3627, 3629, 3630, 3631, 3637, 3656, 3662, 3792, 3804, 3813, 3818, 3819, 3829, 3861, 3891, 3908, 3935, 3945, 3951, 3954)

3591. Menzel, D. H., edited by, Fundamental formulas of physics, New York, Prentice-Hall, Inc., 1955, xxv + 765 pp.

This book is a reference work containing many of the fundamental formulas of mathematical and theoretical physics. Thirty authors have contributed to the 31 chapters of this handbook. As might be expected, authors of some sections assume more familiarity with the subject matter than others do. In some cases there is simply a collection of formulas together with explanations of notations. Other sections have more of a textbook character.

Printing errors (e.g., top, page 415) were noticed very rarely. Errors of omission were noticed in only one case (chap. 8, p. 235), where the subscript g is used to indicate group velocity and then defined as the acceleration of gravity.

The largest single section of the book is the first chapter in basic mathematical formulas (106 pages, about $^1/_7$ of the whole book) by Philip Franklin. This chapter has 21 subsections including algebra, trigonometry, differential calculus, integral calculus, differential equations, vector analysis, tensors, spherical harmonics, Bessel functions, hypergeometric functions, Laguerre functions, Hermite functions, miscellaneous functions, series asymptotic expansions, least squares, statistics, matrixes, group theory, analytic functions, and integral equations.

Chap. 2 (Joseph M. Cameron) is concerned with mathematical statistics including discussion of various distributions, measures of dispersion, fitting of straight lines and polynomials, interval estimation, statistical tests, analysis of variance, standard deviation. Chap. 3 (Donald H. Menzel) is concerned with nomograms and their uses; Chap. 4 (J. W. M. DuMond and E. R. Cohen) Physical constants; chap. 5 (Henry Zatzkis) Classical mechanics, including some advanced dynamics and transformation theory—optical mechanical analogy; chap. 6 (Henry Zatzkis) Special relativity; chap. 7 (Henry Zatzkis) General relativity; chap. 8 (Max Munk) Hydrodynamics and aerodynamics; chap. 9 (Henry Zatzkis) Boundary-value problems in mathematical physics; chap. 10 (Percy W. Bridgman) Heat and thermodynamics, formulas of thermodynamics; chap. 11 (Donald H. Menzel) Statistical mechanics, statistics of molecular assemblies; chap. 12 (Sydney Chapman) Kinetic theory of gases: Viscosity thermal conduction and diffusion; a mixed gas not in equilibrium, gas in equilibrium, nonuniform gas, particular molecular models, and conductivity in a neutral ironized gas with or without a magnetic field; chap. 13 (H. H. Frank and W. Tobocman) Electromagnetic theory; chap. 14 (E. L. Chaffee) Electronics; chap. 15 (P. M. Morse) Sound and acoustics; chap. 16 (James G. Baker) Geometrical optics, including, among other things, a section on Hamilton's characteristic method; chap. 17 (Francis A. Jenkins) Physical optics; chap. 18 (Edward G. Ramberg) Electron optics; chap. 19 (Charlotte E. Moore) Atomic spectra; chap. 20 (L. Herzberg and G. Herzberg) Molecular spectra; chap. 21 (L. I. Schiff) Quantum mechanics; chap. 22 (M. E. Rose) Nuclear theory; chap. 23 (R. W. Williams) Cosmic rays and high energy phenomena; chap. 24 (L. I. Foldy) Particle accelerators; chap. 25 (Conyers Herring) Solid state; chap. 26 (J. H. Van Bleck) The theory of magnetism; chap. 27 (R. E. Powell) Physical chemistry; chap. 28 (W. H. Aller) Basic formulas of astrophysics; chap. 29 (E. W. Wollard) Celestial mechanics; chap. 30 (R. A. Craig) Meteorology; chap. 31 (J. M. Reiner) Biophysics.

The result of the efforts of these authors is a handbook of about 750 pages covering virtually the whole field of physics in extremely condensed form. The book will certainly be useful to many research workers and students.

R. Truell, USA

3592. Schlegelmilch, W., Differential operations in vector analysis and their applications in physics and engineering [Die Differentialoperationen der Vektoranalysis und ihre Bedeutung in Physik und Technik], Berlin, VEB Verlag Technik, 1954, xi + 254 pp.

Purpose of volume is to bridge gap between pure mathematical formalism of vector analysis and its application to physical problems. There are three major parts. The first deals with fundamentals of vector algebra and calculus. The second treats differential operations of the first order, e.g., divergence, curl, etc., with applications to hydromechanics, electricity, potential theory, and curvilinear coordinates. The third considers differential operations of higher order. A large portion is devoted to applications of spherical harmonics. The first boundary-value problem of potential theory is presented. Author plans a second volume on tensor calculus, with applications.

Y. L. Luke, USA

3593. Schouten, J. A., Ricci-calculus, 2nd ed. (Grundlehren der mathematischen Wissenschaften, Bd. 10), Berlin, Springer-Verlag, 1954, xx + 516 pp., 16 figs. DM 55.

This book on tensor analysis is written from a pure mathematics standpoint. It is concerned with many topics which arise in applied mechanics, such as vector analysis, including

vector operators and Stokes' theorem, and the theory of deformation, but they are treated from a fundamental mathematical standpoint, general n-dimensional spaces being studied from the beginning. Thus while this book may be of value, for example, to those concerned with development of the theory of finite strain, it goes beyond the mathematical requirements of most researchers in the field of applied mechanics.

Book gives a very thorough coverage of the field, with a bibliography of about 1400 references. To give some idea of the coverage, a selection of chapter headings is: Lie groups and linear connections, imbedding and curvature, projective and conformal transformations of connections, and variations and deformations.

E. H. Lee, USA

3594. Egerváry, E., Matrix factorization and its application in the solution of systems of linear equations (in German), *ZAMM* 35, 3, 111–118, Mar. 1955.

Every homogeneous system of linear equations can be reduced to an equivalent system of linearly independent equations by decomposing the matrix of the coefficients into two basic factors. In this article a practicable algorithm of factorization is developed, which yields the matrix of coefficients of the reduced systems of equations in triangular form.

From author's summary by T. P. Goodman, USA

3595. Mitra, S. K., Electrical analog computing machine for solving linear equations and related problems, *Rev. sci. Instrum.* 26, 5, 453–457, May 1955.

A new iteration method of solving linear equations is described. The convergence of this method depends on a single scalar parameter which can be predetermined. A brief description of an electrical analog machine for solving linear equations with ten variables based on this iteration method is given. In addition to the solution, the machine gives the largest eigenvalue of the matrix of the linear system.

G. Kron, USA

3596. Albrecht, J., A unified deviation of the equations of Trefftz and Galerkin (in German), *ZAMM* 35, 5, 193–195, May 1955.

The approximation method developed by E. Trefftz for the first boundary-value problem of potential theory and by which the error, measured by means of a positive definite matrix, is reduced to a minimum, was extended by L. Collatz to elliptical differential equations with nonconstant coefficients. The present paper extends the Trefftz minimum principle to the boundary-value problems treated by Collatz. The Galerkin equations are also treated.

W. M. Whyburn, USA

3597. Payne, L. E., and Weinberger, H. F., New bounds in harmonic and biharmonic problems, *J. Math. Phys.* 33, 4, 291–307, Jan. 1955.

Paper gives a new method for obtaining upper and lower bounds for the value of a harmonic function at a particular point and its Dirichlet integral when the boundary values of the function or its normal derivative are prescribed. The principal tools are a Green's identity and an observation that if u is harmonic, so is $r\ \partial u/\partial r$. For the application of the present method, the boundary shape must be assumed to be star-shaped with respect to at least one point. In the methods proposed by Prager, Synge, Maple, Diaz, Greenberg, and others, the upper and lower bounds are obtained separately from two different approximating sequences; in the present method, only one sequence of approximating functions is necessary to give both upper and lower bounds. In the latter part of the present paper, the method is extended to the biharmonic clamped plate problem.

K. Washizu, Japan

3598. Young, D., and Hess, P. N., On the stability of harmonic solutions of a modified form of Duffing's equation, *Proc. second U.S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 79–84.

Analysis of the stability of periodic solutions of Duffing's equation indicates certain unstable regions. This paper reports an investigation of the actual behavior in these theoretically unstable regions. The work was carried out on an analog computer using a modified form of the equation which has an exact harmonic solution. The results verify that the harmonic solutions became unstable in the predicted regions. In addition, it is found that certain unusual nonharmonic periodic solutions are stable in these regions.

From authors' summary by N. Minorsky, France

3599. Misovskikh, I. P., Application of Chaplígin's method to the solution of the Dirichlet problem for a special type of elliptic differential equations (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* 99, 13–15, 1954.

Consider the equation $\Delta u = f(x, y, u)$ in a bounded, simply connected region D with sufficiently smooth boundary S. Suppose u vanishes on S. If $f_u > 0$ and $f_{uu} \leqq 0$ in and on the boundary of D, author defines the sequence of functions u_n with $u_0 = 0$ satisfying

$$\Delta(u_n - u_{n-1}) = f_n(x, y, u_{n-1})(u_n - u_{n-1}) + f(x, y, u_{n-1}) - \Delta u_{n-1}$$

and shows that $u_n \leqq u_{n-1}$ and that $u_n \to u$. Moreover, if $f(x, y, V) - \Delta V \leqq 0$, and V vanishes on S, then $u_n \geqq V$.

A sequence of functions v_n with $v_n \geqq v_{n-1}$ is defined by means of a somewhat more complicated recursion where also $v_n \to u$. The case $f_u \geqq 0$ with no assumption on f_{uu} is also treated, but again the recursions are more complicated.

A. S. Householder, USA

3600. Basov, V. P., Construction of solutions of a class of systems of linear differential equations (in Russian), *Prikl. Mat. Mekh.* 18, 313–328, 1954.

The equation dealt with is $\dot{x} = (P + t^{-\gamma}Q(t)x$, where x is an n-vector, P a constant matrix, Q a continuous and bounded matrix for $t \geqq t^*$, and γ is a positive constant. Author gives the form of a solution corresponding to any given real characteristic root ρ of P such that no other characteristic root of P has ρ for real part. The paper follows the general ideas of N. P. Erugin [*Trudi Mat. Inst. Steklov* 13, 1946].

S. Lefschetz, USA

3601. Mikeladze, S. E., Numerical solution of boundary problems for nonlinear ordinary differential equations (in Russian), *Soobshchen. Akad. Nauk Gruzin. SSR* 14, 133–137, 1953.

The differential equation $y^{(n)}(x) = f(x, y, y', \ldots, y^{(n-1)}$ is replaced by the system

$$y^{(k)}(x) = \sum_{\nu=0}^{n-k-1} x^{\nu} y^{(k+\nu)}(0)/\nu!$$
$$+ [(n-k-1)!]^{-1} \int_0^x (x-t)^{n-k-1} y^{(n)}(t)\,dt$$

where $k = 0, 1, \ldots, n - 1$. Author then proposes to replace the integrals of this system for numerical approximations, with x restricted to the discrete set of values $x = \sigma h$, σ an integer. The resulting algebraic system is solved for y and its derivatives at arguments of this set. In the example chosen, $y'' = ay(1 - 0.5y'^2)$, this final solution is accomplished by iteration.

R. E. Gaskell, USA

3602. **Krein, M. G., On a new method of solving linear integral equations of the first and second kinds,** *Doklady Akad. Nauk SSSR (N.S.)* **100,** 3, 413–416, 1955. (Translation by M. D. Friedman, 2 Pine St., W. Concord, Mass.)

3603. **Kolmogorov, A. N., and Fomin, S. V., Elements of the theory of functions and of functional analysis. Vol. I: Metric and normalized spaces [Elementi teoriyi funktsii i funktsionalnogo analiza. Metricheskiye i normirovanniye prostranstva],** Izdat. Moskov Univ., 1954, 154 pp.

Modern methods of functional analysis and related questions become more and more important in technical science and theoretical physics. Attention should be called at least to fundamental significance of abstract spaces (Hilbert's space, Banach's principle), of linear functionals and operators in such spaces [see AMR **7,** Rev. 3784], of operational equations (implying, as special case, theory of integral equations), etc. Courses on these subjects are given not only by mathematical, but also by physico- and mechanico-mathematical faculties of the Russian universities.

Book in question constitutes the first part of a greater project originating in the lectures at the Moscow university. It is easily readable for calculating engineers and physicists with only basic knowledge of algebra and elementary calculus.

Subject is divided into four chapters. The first gives necessary elements of the theory of finite and infinite sets, including the general definition of a function. Following main part is devoted to metric spaces; engineer's attention is called especially to the theory and use of Banach's principle, an excellent foundation of the well-known iteration methods. Third chapter deals with linear normalized spaces, emphasizing important facts about linear functionals and operators. Final section treats the spectra of operators and explains the theory of linear operational equations. The volume ends with a good index of the subjects treated.

Book abounds in original ideas and emphasizes philosophical points of view. Style is excellent, print good. Reviewer warmly recommends this fine little work of the renowned Russian savants and pedagogues not only to mathematicians, but also to calculating physicists and engineers. V. Vodička, Czechoslovakia

3604. **Golovina, A. M., A nondeterminantal method of construction of nomograms** (in Russian), Nomographic collection, 98–106, Izdat. Moskov. Gos. Univ., Moscow, 1951.

Textbooks on nomography show that the three functions of the scales of a nomogram must satisfy the Massau determinant. This determinant may be used in the design of the nomogram. However, simpler techniques are frequently possible. In the present work, the relation between the points of a circle and their stereographic projection onto a tangent straight line is used to display several commonly sought nomographic relations. [See Whittaker and Robinson, "Calculus of observations," 3rd ed., Blackie, London-Glasgow, 1940, p. 128.] Projective transformations of these nomograms give other conic sections which, for some purposes, have more desirable scales. M. Goldberg, USA

3605. **Boonshaft, J. C., Measurement errors—classification and interpretation,** *Trans. ASME* **77,** 4, 409–411, May 1955.

3606. **Newell, G. F., Mathematical models for freely-flowing highway traffic,** *J. Oper. Res. Soc. Amer.* **3,** 2, 176–186, May 1955.

An attempt is made to construct models for the motion of cars on a highway in a manner analogous to the way one treats the motion of molecules in a gas as described by the kinetic theory of gases. In particular, the comparison is made between a traffic flow at very low volumes and the motion in a rarefied gas. From this, it can be expected that even a very crude model of the interaction between individual cars will give a quite reasonable description of the collective behavior of large groups of cars. Some simple estimates of the dependence of average velocity on density and distribution of cars in various lanes of a multilane highway based upon very crude models seem to confirm this expectation.

From author's summary

3607. **Pike, E. W., Some statistical methods for evaluation of experimental results,** *Trans. ASME* **77,** 4, 401–403, May 1955.

Statistical examination of mass-production methods results in improvement, better quality control, and more uniformity of billions of dollars' worth of industrial products produced each year by repetitive processes. This paper describes the logic and methods used in evaluating and organizing equipment tests.

From author's summary

3608. **Dickins, B. G., Operational research,** *Proc. 3rd AGARD Gen. Assembly, AGARD* AG6/P3, 85–89, Sept. 1953.

3609. **DeVries, L., English-German technical and engineering dictionary, 1st ed.,** New York, Toronto, London, McGraw-Hill Book Co., Inc., 1954, xv + 997 pp.

This scholarly work is a welcome addition to the German-English part of the dictionary published in 1950 [AMR **4,** Rev. 512]. Author's competence and untiring efforts as well as the panel of collaborators and impressive list of reference books consulted make this dictionary the most complete and modern work of its kind. It will be an indispensable reference book and tool for English-speaking persons concerned with German technical literature, research, industry, and commerce.

L. and G. Warga, USA

3610. **The computer directory, 1955, Berkeley, E. C., editor,** *Computers and automation* **4,** 6, 162 pp., June 1955.

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 3591, 3672, 3785, 3857, 3955)

3611. **Higdon, A., and Stiles, W. B., Engineering mechanics, 2nd ed.,** New York, Prentice-Hall, Inc., 1955, xix + 579 pp. $7.95.

Present text is the second edition, the first having appeared in 1948. Revisions from first edition include: more than 40% new problems, new format, larger type, new illustrations, reorganization of certain chapters, addition of more practical examples, and the addition of a chapter on virtual work.

In a foreword by Gilkey, mechanics texts are divided into three broad classes: (1) Philosophical, with major emphasis on theoretical aspects; (2) "the more strictly applied" with emphasis on *method* of analysis; and (3) "applied" with emphasis on formula use. Present text is placed in class (2); reviewer agrees with general classifications and with description of present text as class (2). Publisher claims this is a revision of "the most widely used engineering mechanics text on the market."

The general arrangement is as follows, by chapter titles: Basic concepts; Resultants of force systems; Centroids and center of gravity; Equilibrium; Friction; Second moments or moments of inertia; Method of work; Kinematics—absolute motion; Kinematics—relative motion; Kinetics—force, mass, and acceleration; Kinetics—work and energy; Kinetics—impulse and momentum; Mechanical vibrations.

Reviewer believes that fundamental concepts are handled quite well, that fundamental quantities are defined in reasonable and correct ways, and that, on the whole, this is a very good text for

engineering-mechanics courses as taught in most universities in this country. However, there are two criticisms which the reviewer would like to offer. In some instances the expository material is too brief, probably as the result of including more than 1100 problems in a text on both statics and dynamics within 585 pages. For example, the chapter on virtual work is 20 pages in length, of which 13 are devoted to problems and examples. Again, in the chapter on vibrations, only undamped systems are treated and the topic of resonance is disposed of in nine lines; in the chapter on relative motion, the Coriolis force is treated in one short paragraph which will surely not leave the student with any understanding of the phenomenon. Other instances of similar nature may be pointed out easily. While reviewer likes the book, he feels that perhaps the trend in the United States toward multitudes of problems in texts, as opposed to the scarcity of problems in European texts, has reached the saturation point, or even greatly surpassed it. Other teachers may not agree.

The other criticism is related to the illustrations—in general, they are clear and well designed; however, in some instances they have simply been reduced by such a large factor that the lettering is entirely too small for easy reading (this appears to be a common failing of United States texts and is by no means restricted to the text under review). Students with less than average vision will have just cause for complaint.

One can scarcely glance through the text without becoming aware of the excellent use of the free-body diagram technique. It is probably this fact, more than any other, which causes reviewer to like the book. Undoubtedly, this text will find favor in many institutions, and rightly so. H. N. Abramson, USA

3612. Mandelker, J., The derivation of a new kinetic energy formula from the energy aspect of matter, *Proc. second U.S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., June 1955, 135–141.

Showing that the motion of a body whose mass increases with velocity is equivalent to motion with resistance of the character of a continuous inelastic impact, author derives in connection with the relation between mass and energy mc^2 on classical grounds a formula for kinetic energy of the form

$$E_k = m_0c^2[1 - (1 - v^2/c^2)^{1/2}]$$

whereas the expression which he obtained for total work performed is identical with that of relativity mechanics. Author concludes that in the expression for total work there are contained two different types of energy as in a resisting medium, a kinetic and a nonkinetic dissipative one, from which, in the limit $v = c$, the former attains a definite maximum value m_0c^2, whereas the latter as well as the total work performed increases infinitely. Author states that the kinetic formula derived conforms rigorously with relativistic kinematics and overcomes the difficulty which arises in relativity theory with regard to Lagrange's function L.

F. Krupka, Czechoslovakia

3613. Artobolevskiĭ, I. I., Zinov'ev, V. A., and Édel'stein, B. V., Collection of problems on the theory of mechanisms and machines [Sbornik zadač po teorii mehanizmov i mašin], 2nd ed., Moscow, Gos. Izdat. Tekh.-Teor. Lit., 1951, 195 pp. 4.40 rubles.

Many recent Russian textbooks on mechanisms do not include problems needed for the engineering student. The present work fulfills this need. Answers are given in the back of the book and, depending upon the demands of the problem, are qualitative, numerical, or graphical. The arrangement is by topic, following the works of the senior author. Each set of problems is preceded by a brief discussion of the general principles. The following topics suggest the scope of the work: kinematic pairs, composition of mechanisms, classification, degrees of freedom, trajectories, velocity and acceleration diagrams, centrodes, toothed mechanisms, design of mechanisms and cams, forces, friction, balancing of rotating mechanisms. M. Goldberg, USA

3614. Rosenaurer, N., Determination of the state of velocity and acceleration in the Stephenson's link motion, *J. Instn. Engrs., Austral.* **27,** 3, 67–68, Mar. 1955.

3615. Levitskiĭ, N. I., and Sahbazyan, K. H., The synthesis of spatial four-link mechanisms with lower pairs (in Russian), *Trudi Sem. teor. Mash. Mekh.* **14,** 54, 5–24, 1954.

The four-bar mechanism made of two skew shafts carrying cranks joined by a connecting rod through ball-and-socket joints can be specified by eight parameters. By analytical geometry, the relations between these parameters and the variable angles are derived. These equations may be used for approximating a desired curve by calculating the required parameters to pass the curve through selected points or by other curve-fitting processes (least squares or other criteria). The equations are used in a numerical example in which eight parameters are calculated. Special cases are considered in which fewer parameters, down to only three, are subject to calculation. M. Goldberg, USA

3616. Zinov'ev, V. A , Design of spatial four-link mechanisms according to a complete set of parameters (in Russian), *Trudi Inst. Masinoved* **14,** 55, 49–62, 1954.

This is an independent solution to a set of problems similar to those considered by Levitskiĭ and Sahbazyan [title source, 14, 54, 5–24, 1954]. M. Goldberg, USA

3617. Freudenstein, F., Approximate synthesis of four-bar linkages, *Trans. ASME* **77,** 6, 853–861, Aug. 1955.

See AMR **8,** Rev. 1554.

3618. Schmid, Wilhelm, Determination of the double points of a coupling curve [Konstruktion der Doppelpunkte einer Koppelkurve], Bericht, Mathematiker-Tagung (Berlin), 271–279, Jan. 1953; Berlin, Deutscher Verlag der Wissenschaften, 1953. DM 27.80.

The coupler curves traced by points on the connecting rod joining two cranks are sextic curves with three double points. The triangle F made by the three foci (two of the foci are the axes of the cranks) is similar to the triangle of the tracing point and the ends of the connecting rod. The triangle F and the triangle D of the double points lie in an isogonal position on the same focal circle. The isogonal inverse of any line with respect to D is a conic section which circumscribes D. By constructing this conic and its intersections with the focal circle, the double points are found. Eckhart [*Maschinenbau* **15,** 697–698, 1936] used a hyperbola for this conic. The author uses a parabola also. In addition, the construction considers isolated and imaginary double points.

M. Goldberg, USA

3619. Phillips, J. R., A graphical method for skew forces and couples, *Austral. J. appl. Sci.* **6,** 2, 131–148, June 1955.

Paper deals with graphical resolution of forces in space. Analogy is drawn with equilibrium of a body in two dimensions which can be supported by three wires passing through a given point, while in three dimensions, four wires are required which must lie "... as generators for the same family on the surface of some hyperboloid."

Reference is made to practical application in design of plowing equipment. However, results could likely be obtained more

easily by analytical methods, and paper appears to be primarily of academic interest.

Descriptions and diagrams are clear and photographs of ingenious three-dimensional models are presented to illustrate principles. C. D. Pangelley, USA

3620. Michel, J. G. L., Errors of friction wheel integrators, *J. sci. Instrum.* **32,** 2, 43–44, Feb. 1955.

Sharp-edged friction wheels moving across hard surfaces with a combined rolling and sliding motion are used as units for integration in a number of instruments varying in complexity from planimeters to differential analyzers. In these applications it is assumed that, providing the bearing friction of the wheel is sufficiently small, the rotation of the wheel is a true representation of that component of its motion across the surface which is tangential to the wheel. This paper shows that, for finite bearing, friction (however small), this is not true when there is any nontangential (sliding) motion of the wheel; an expression is adduced for the amount of error, with a numerical example of the magnitude of this error in a type of integrator used in differential analyzers. It is pointed out that errors due to this cause may always be reduced to negligible proportions in the case of the differential analyzer, at the expense of increasing the time of solution. From author's summary

3621. Miele, A., Optimum climbing technique for a rocket-powered aircraft, *Jet Propulsion* **25,** 8, 385–391, 399, Aug. 1955.

Paper contains a preliminary investigation of the flight path which minimizes both the time and the propellant expenditure necessary to fly a rocket-powered aircraft from a given combination of speed and altitude to another combination of speed and altitude. From author's summary

3622. Schrode H., Reduction of the shimmy tendency of tail and nose-wheel landing gears by installation of specially designed tires, *NACA TM* 1391, 13 pp., July 1955 (translated from the German language.)

Shimmy of tail and nose wheels may be eliminated by installation of dampers and use of large trail; however, this produces construction and operational disadvantages. It is more favorable to employ, instead of the customary tail-wheel tires, tires with lesser shimmy tendency. A description of the best possible form for these tires follows; furthermore, a few general concepts regarding the effects of the condition of the tire, of the type of rolling motion, and of the loading are discussed.

From author's summary

3623. Starks, H. J. H., and Lister, R. D., Experimental investigations on the braking performance of motor vehicles, *Instn. mech. Engrs. Auto. Div.* no. 1, 31–44, 1954–1955.

Servomechanisms, Governors, Gyroscopics

⊗3624. Behar, M. F., editor, Handbook of measurement and control, 2nd ed., *Instruments and Automation* **27,** 12 (part 2), Dec. 1954.

Book is published as part 2 of Dec. 1954 issue of *Instruments and Automation*. The second edition of a similar work published in 1951, it describes basic types of instruments used for static or slowly varying measurements of temperature, pressure, dimension, flow, physical properties, radio activity, etc. Separate chapters are included on fidelity of response to input changes and on the fundamentals of servomechanisms and automatic process control. Many excellent tables and charts assist in the selection of proper instrumentation. Broad and general in treatment, book serves as a valuable introduction to the problems of securing accurate measurements. C. E. Balleisen, USA

3625. Moshos, G. J., Analog interpolation for automatic control, *J. Assoc. Computing Mach.* **2,** 2, 83–90, Apr. 1955.

Author describes a device converting discrete digital data on punched cards to a continuous analog voltage. The amount of input data necessary is minimized by higher-order interpolation and a provision for automatic error compensation. Device consists of two integrators and a linear interpolator.

This device has been used for control of an automatic turbine blade-cutting system and should be useful in many similar applications. Reviewer believes that the device would be useful in applications other than automatic fabrication; e.g., in plotting a continuous curve from digital data. G. C. Wallick, USA

3626. Jaumotte, A. L., Control of single shaft, open cycle, gas turbines for constant speed and constant maximum temperature (in French), *Acad. roy. Belgique, Bull. Cl. Sci.* (5) **41,** 486–499, 1955.

Conventional method of load change in constant-speed open-cycle gas turbines by variation of turbine inlet temperature has the inherent disadvantage that the temperature decreases at partial load. The thermal efficiency decreases rapidly.

Author compares the performance of conventional method with one in which the compressor is equipped with adjustable guide vanes. The inlet temperature is kept at constant maximal value. Performance curves are calculated for some cases with and without regeneration and with and without intercooling in compression. Improvement in thermal efficiency is attained in all cases except for nonregenerating and nonintercooled case.

The title "control" (regulation) is somewhat misleading. No control dynamics is treated. "Performance characteristics" would be more appropriate. L. S. Dzung, Switzerland

3627. Blunden, W. R., Integrators for computers and control systems, *Prod. Engng.* **25,** 6, 168–175, June 1954.

3628. Otto, E. W., Gold, H., and Hiller, K. W., Design and performance of throttle-type fuel controls for engine dynamic studies, *NACA TN* 3445, 39 pp., Apr. 1955.

The results of an analytical and experimental investigation of the steady-state and dynamic characteristics of three types of throttle-controlled fuel systems are presented. The investigation covers the effect of output pressure on the controlled flow and the dynamic response of output flow to throttle movement. Results show that linearized analysis provides an adequate description of the dynamic response. The best system tested showed a usable frequency response to 300 cps.

From authors' summary

Vibrations, Balancing

(See also Revs. 3598, 3611, 3670, 3757)

⊗3629. Haag, J., Vibratory motions [Les mouvements vibratoires], vol. II, Paris, Presses Universitaires de France, 1955, viii + 253 pp. (paperbound).

This second volume, published two years after the death of the author at age 71, was prepared for the press from a complete manuscript by his assistant, P. Langue. Whereas the first volume dealt with systems of a single degree of freedom, this one gives general theories on many degrees of freedom, linear and nonlinear, with practical applications mostly on two- or three-degree sys-

tems. These examples cover a wide range: gyroscopes, automobiles, aircraft landing gears, bicycles, various pendulum combinations, and clocks. The author, being director of the Institute for Chronometry in Besançon, France, places particular emphasis on time-indicating devices, which gives these two books a character different from the usual treatises on the subject.

J. P. Den Hartog, USA

3630. Cohen, H., On subharmonic synchronization of nearly-linear systems, *Quart. appl. Math.* **13,** 1, 102–105, Apr. 1955.

Equations giving conditions for subharmonics and synchronization are derived for equations of form $\ddot{y} + \epsilon f(y)\dot{y} + \omega_0^2 y = A \cos (n\omega t + \varphi)$ (y and A of order unity; ϵ small) in terms of coefficients in Fourier expansion of $f(y)$. Extension to include $(y, \dot{y})$ is indicated.

R. N. Arnold, Scotland

3631. Morris, G. R., A differential equation for undamped forced non-linear oscillations, I, *Proc. Camb. phil. Soc.* **51,** part 2, 297–312, Apr. 1955.

Paper treats the equation $\ddot{x} + 2x^3 = e(t)$ in which $e(t)$ is an even periodic function. Some characteristics of the generalized equation $\ddot{x} + g(x) = e(t)$ are first considered and then the treatment is specialized. A criterion for periodic solution is found and also some properties of general solutions. It is shown that every solution of the special equation has an infinity of stationary points. It discusses large solutions over one and several cycles, approximations to desired solutions, and a certain class of periodic solutions.

M. G. Scherberg, USA

3632. Stoker, J. J., Non-linear vibrations of systems with several degrees of freedom, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 33–43.

Paper gives a comprehensive review of the single-degree-of-freedom problem, pointing out the great difficulties involved in extension of the theory to more degrees of freedom. A general discussion of Poincaré's perturbation method applied to a multi-degree system follows, with an application to a simple two-mass case. Some general remarks on continuous systems conclude the paper.

J. P. Den Hartog, USA

3633. Sethna, P. R., Steady-state motion of one and two degrees of freedom vibrating systems with a nonlinear restoring force, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 69–78.

Author treats free and forced vibrations of systems of one and two degrees of freedom, with and without damping. Conventional analytical methods are employed, yielding the response curves. Most interesting feature of paper is comparison of response curves obtained from analytical methods with those obtained from an electronic analog computer. Systems treated contain nonlinear springs of hardening type only.

H. N. Abramson, USA

3634. Huang, T. C., Subharmonic oscillations in nonlinear systems of two degrees of freedom, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 95–100.

Author studies subharmonics of order $1/3$ by well-known method of Fourier series expansion. Undamped system is first treated, followed by an analysis for the system with viscous damping included. Results are given as analytical expressions for the Fourier coefficients; reviewer would like to have seen results expressed by response curves and more fully discussed. No references are cited.

H. N. Abramson, USA

3635. Kats, A. M., Biharmonic vibrations of a dissipative nonlinear system induced or sustained by a harmonic disturbing force (in Russian), *Prikl. Mat. Mekh.* **18,** 4, 425–444, July/Aug. 1954.

Solutions of the equation $\ddot{x} + k\dot{x} + x + x^3 = R \sin \omega t$ of the form $x = C + A \sin (m\omega t + \phi) + B \sin (m\omega t + \psi)$ are sought for (a) $m = 1, n = 3$; (b) $m = 3, n = 1$; (c) $m = 1, n = 2$; and (d) $m = 2, n = 1$. The constants A, B, C, ϕ, and ψ are found by the method of "undetermined coefficients" of 1, $\sin m\omega t$, $\cos m\omega t$, $\sin n\omega t$, $\cos n\omega t$, neglecting other harmonics. Results for the four cases are discussed briefly, and special properties of some numerical examples are plotted.

R. E. Gaskell, USA

3636. Schulte, C. A., and Riester, R. A., Effects of mass distribution on critical speeds, *Proc. second U.S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 101–110.

Paper gives the results of an investigation of the critical speeds of overhung rotors excited by rotational unbalance. Rotors of approximately identical weights, but different mass distributions, were used to determine both analytically and experimentally the influence of the gyroscopic moment on critical speeds. No effort was made to provide external stimulus at frequencies other than the running speed. Nine different shaft and rotor combinations were investigated. In each case, actual tests revealed a resonance condition corresponding to the critical speed of forward precession. In six of the nine cases, the critical speed of backward precession was observed.

From authors' summary by R. G. Boiten, Holland

3637. Plunkett, R., Semi-graphical method for plotting vibration response curves, *Proc. second U.S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 121–126.

Author demonstrates simple technique for constructing vibration velocity amplitude plots as a function of frequency for distributed-parameter systems. The response is calculated utilizing graphical procedures to sum the normal mode responses. Results are given for two cases involving a free-free beam.

Reviewer agrees with author that method as described is applicable only to relatively simple cases.

R. B. Grant, USA

3638. Mindlin, R. D., and Deresiewicz, H., Timoshenko's shear coefficient for flexural vibrations of beams, *Proc. second U.S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 175–178.

Authors recommend determining shear coefficient in beam equation so that the equations will yield more accurate values of the high frequencies. If the deflection is set equal to zero, a uniform rotational motion of the normals to the elastic axis is defined with an associated value of frequency. A similar value of high frequency is obtained by the authors from the theory of elasticity by setting both lateral components of displacement equal to zero. Equating the two frequency formulas thus obtained provides an equation which determines the shear coefficient if the rotary inertia value is assumed to be known. Reviewer would prefer to use this equation to determine a reduced rotary inertia value, assuming that the shearing coefficient is known. This would allow one to use the same differential equations for static and dynamic analysis.

The lowest antisymmetric mode of axial displacements from elasticity is not planar and may be considered to define a rotary inertia value somewhat smaller than that given by the assumption that plane sections remain plane. Thus, one can justify a reduction of the rotary inertia for high frequency analysis. Also, it should be noted that, in the analysis of thin-walled beams with

rigid ribs, it is found that the shearing stiffness is independent of the distribution of shearing stress on the cross section.

Authors present values of shear coefficient for rectangular, elliptical, and ovaloid sections ranging from approximately 0.8 to 0.9 in place of the well-known value of 2/3 for a rectangle.

S. U. Benscoter, USA

3639. Neuber, H., Properties of torsional frequencies and the derivation of formulas for limiting values (in German), *Ing.-Arch.* **22,** 4, 258–267, 1954.

Purpose of the paper is to establish simple rules and upper and lower bounds for the natural frequencies in torsional systems consisting of lumped moments of inertia and mass-free shafts. The upper and lower bounds are found by comparing the actual system with various other systems modified by increasing (to infinity) or decreasing (to zero) either the stiffnesses of members or the values of moments of inertia. The results flow from a discussion of the frequency determinant

K. Klotter, USA

3640. Alblas, J. B., On the excitation of mechanical vibrations of low frequencies (in Dutch), *Ingenieur* **67,** 29, 101–103, July 1955.

A calculation has been given for the nonharmonic force exerted by a vibration generator consisting of rotating weights. Design parameters are included.

From author's summary

3641. Morice, P. B., Energy approximations applied to problems of structural equilibrium, stability and vibrations, *Struct. Engr.* **33,** 6, 173–180, June 1955.

Minimal energy relationship is derived from Hamilton's principle for problems stated, linear vibration only. Rayleigh-Ritz and Lagrangian multiplier methods are derived and Galerkin indicated. Minimal energy is used for approximate solutions of three simple examples.

R. Plunkett, USA

3642. Baird, R. C., Wind-induced vibration of a pipe-line suspension bridge, and its cure, *Trans. ASME* **77,** 6, 797–804, Aug. 1955.

Paper concerns a solution to a critical pipe-line bridge-vibration problem. The answer to the problem resulted from the application of scientific research methods. As the first step toward a solution, careful measurements were made which laid bare the fundamental cause of the trouble. Following this, several possible solutions were conceived, and the most practical appearing one was selected for testing. Dynamic tests on models were made to verify the choice and to aid in full-scale design. Finally, a full-scale aerodynamic vibration damper was applied to the suspension bridge and the results checked by scientific measurements. The resulting solution for preventing vibration of suspension bridges is thought to be completely new, and the subject pipeline bridge to be the first of its kind to which it has been applied.

From author's summary

3643. Scruton, C., Wind-excited oscillations of tall stacks, *Engineer, Lond.* **199,** 5185, 806–808, June 1955.

Existing aerodynamic knowledge provides a simple explanation of the aerodynamic instability of a stack, and this is supported by some model experiments carried out at the National Physical Laboratory.

From author's summary

3644. Trumpler, W. E., Jr., and Owens, H. M., Turbine-blade vibration and strength, *Trans. ASME* **77,** 3, 337–341, Apr. 1955.

See AMR 7, Rev. 2087.

3645. Cadambe, V., Vibration problems in engineering, *J. Instn. Engrs., India* **35,** 1, 63–80, Sept. 1954.

The purpose of this paper is to present a brief survey of vibration problems encountered in many branches of engineering.

From author's summary

3646. Stolte, V. E., Vibration damping of elastically supported engines (in German), *Motortech. Z.* **15,** 11, 316–322, Nov. 1954.

3647. Soroka, W. W., Shock isolation, *Prod. Engng.* 26, 6, 167–171, June 1955.

Author derives response of elastically mounted mass excited by a half-sine motion of its base. Material is well known, but presented in convenient nondimensional form.

M. C. Junger, USA

3648. Cadambe, V., Vibration in foundations, *J. Instn. Engrs., India* **35,** 1, 80–86, Sept. 1954.

Paper presents a brief résumé of work done in the U.K., the U.S.A., the U.S.S.R., Germany, and in other countries on the analysis of ground vibrations due to natural causes and the working of machinery and industrial plants.

From author's summary

3649. Gauss, F., Vibration behavior of vehicles with pneumatic tires (in German), *Forsch. Geb. Ing.-Wes.* **21,** 3, 87–95, 1955.

The vehicle is idealized by a two-mass system, one mass representing an axle and the other mass part of the carriage. Springs as well as dampers are assumed between carriage and axis and between axle and ground. This system allows the study of vertical translational oscillations of the vehicle. The equations of motion are established and are solved for steady and for transient excitation resulting from road roughness. Numerical results are presented for a large number of values of the parameters (masses, springs, dampers, and type of excitation) of the system.

A. I. van de Vooren, Netherlands

3650. Kumai, T., Vertical vibration of ships, *Rep. Res. Inst. appl. Mech. Kyushu Univ.* **3,** 9, 25–43, Apr. 1954.

A simple formula for estimating the critical frequencies of the vertical vibration of ships' hulls, including high mode criticals, is derived from the theoretical investigations on the flexural vibration of the beams of variable cross section, taking the effects of the shear deflection and the rotational inertia of the section into consideration. The critical frequencies and the vibration profiles obtained by the calculations are compared with those measured in actual ships.

From author's summary

3651. Payne, P. R., Helicopter vibration in the tip path plane, *Aircr. Engng.* **27,** 316, 180–189, June 1955.

In-plane vibration of a balanced helicopter rotor is caused by variations with azimuth of the in-plane forces acting on individual blades. These forces may be summarized under three headings: (1) "Induced forces" caused by the inclination of elemental lift vectors relative to the axis of rotation. (2) "Profile drag forces:" variations are caused by changes with azimuth angle and airspeed of the individual blade elements. (3) "Coriolis forces," which are caused by blade flapping, which brings about a variation of blade moment of inertia about the axis of rotation. Equations are developed in this paper for the resultant hub force due to each of these forces, on the assumptions of small flapping hinge offset. It is assumed that blades are linearly twisted and tapered, an assumption which in practice can be applied to any normal rotor.

It is shown that by suitably inclining the mechanical axis it is possible to balance out the worst induced and profile drag vibrations by the Coriolis one, which can be made to have opposite sign. If the mechanical axis is fixed in the fuselage, this suppression is fully effective for one flight condition only. In multirotor helicopters, vibration suppression can be extended over a much wider range by varying the fuselage attitude. The logical result of this analysis is, for single rotor helicopters, a floating mechanical axis which can be adjusted or trimmed by the pilot. This would be quite simple to do on a tip-driven rotor, and has already been achieved with a mechanical drive on the Doman helicopter.

The more important causes of vibration from an unbalanced rotor are next considered, attention here being confined principally to fully articulated rotors, which are the most difficult to balance because the drag hinges tend to magnify all inaccuracies in finish and balance. From a brief discussion of the vertical vibration of an imperfect rotor it is shown that some contemporary methods of "tracking" are fundamentally wrong. Finally, the vibration due to tip-mounted power units is described. In discussing the effect of a vibratory force on a helicopter, a simple response chart is developed, and it is thought that its use could be well accepted as a simple standard for general assessment purposes.

In the development of equations for vibration the following points of general technical interest are put forward: An equation for induced torque is developed which includes a number of hitherto neglected parameters. A new form of equation for mean lift coefficient of a blade is suggested. The simple Hafner criterion for flight envelopes is shown to give rise to considerable error, and the use of Eq. (28) is suggested in its place. The variation of profile torque with forward speed is given, and the increase due to delta varying round the disk is expressed as an explicit equation, thus allowing considerable improvement in the present methods of allowing for this effect.

From author's summary by T. P. Torda, USA

Wave Motion in Solids, Impact

(See also Revs. 3664, 3672, 3735, 3778)

3652. Eubanks, R. A., Muster, D., and Volterra, E., On the attenuation of a sinusoidal pulse in a cylindrical specimen held between elastic bars, *Proc. second U.S. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 193–200.

Authors present some formal solutions to the one-dimensional wave equation for pulse loadings and three different types of stress-strain laws. The laws considered are: (1) Elastic (Hookean model); (2) elastoviscous (Voigt model); (3) hereditary (Boltzmann model). Reflections from the ends of the specimen are not considered. The treatment is strictly mathematical. Reviewer is of the opinion that a study of the contrast between the given solutions and the response of real materials to pulse loading is greatly needed. W. H. Hoppmann, II, USA

3653. Oshida, I., On the theory of the mechanical properties of liquids in the supersonic and hypersonic region, *Mem. Fac. Engng. Univ. Nagoya* **2**, 1, 29–49, Apr. 1950.

The general stress-strain relations for plastoelastic bodies having any number of times of relaxation are obtained. The author's previous theory and Frenkel and Obrtatzov's theory are included as special cases.

The elastic waves in such a body are discussed, and the results compared with those of the molecular theory. It was shown that the mechanism postulated by Kneser, in his theory of the absorption of the supersonic wave in gases, plays an important role also in liquids. By this mechanism, the behavior of most liquids for supersonic frequency is comprehensible, at least qualitatively. The effects of viscosity and conduction of heat are discussed. The existence and the high velocity of the hypersonic waves, or the elastic waves of extremely high frequencies caused by thermal agitation, were also explained, being based on the same mechanism.

There are, however, some exceptions, including water, for which the other mechanism (that is, perhaps the rearrangement of molecules) predominates.

As the transverse waves may also exist, they are discussed briefly at the end. From author's summary

Elasticity Theory

(See also Revs. 3666, 3668, 3669, 3670, 3675, 3682, 3686, 3688, 3731, 3762)

3654. Sternberg, E., and Eubanks, R. A., On the singularity at a concentrated load applied to a curved surface, *Proc. second U.S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 237–245.

Authors propound the questions: Under what circumstances does Boussinesq's solution for the semi-infinite elastic body, bounded by a plane and acted upon by a concentrated surface load, supply the complete singularity appropriate to a concentrated load applied to a curved boundary? What are the supplementary singularities needed in the event the Boussinesq singularity fails to yield a regular residual problem? Both questions are answered for the case of a surface of revolution whose axis coincides with the axis of the load. R. D. Mindlin, USA

3655. Galin, L. A., Contact problems of the theory of elasticity [Kontaktnye zadaci teorii uprugosti], Moscow, Gosud. Izdat. Tekh-Teor. Lit., 1953, 264 pp. 8 rubles.

Author deals exhaustively with the theoretical aspects of the problems arising from contact of two bodies at least one of which is elastic. A survey of work done on such problems inside and outside Russia is included.

There are two main parts, the first dealing with the plane, the second with the half-space problem. All basic formulas are deduced from first principles, and a summary of the relevant work on Cauchy integrals, taken over infinite lines, on the solution of the Riemann-Hilbert problem, and on three-dimensional potential theory is given in order to make the book self-sufficient.

The particular cases considered comprise various shapes of rigid and elastic stamps, with or without friction and cohesion, stationary or moving, on a half plane of isotropic or anisotropic material; circular, elliptic, triangular cylinders with or without friction pressing on the half space. One typical general result is that the pressure distribution under a rigid stamp is the same for orthotropic as for isotropic half planes, provided the boundary is parallel to one of the axes of orthotropy.

The presentation is clear and detailed and the book illustrates well the use of function theory in elasticity.

J. R. M. Radok, Australia

3656. Rivlin, R. S., and Ericksen, J. L., Stress-deformation relations for isotropic materials, *J. rational Mech. Analysis* **4**, 2, 323–425, Mar. 1955.

The object of the present paper is to derive expressions for the components of the stress tensor in terms of the deformation, for materials with more complex mechanical properties than those discussed in the previous theories. We assume that the materials are homogeneous and isotropic and that the components of stress depend only on the gradients of displacement, velocity,

acceleration, second acceleration, ...$(n - 1)$th acceleration, or on the gradients of velocity, acceleration, second acceleration,... $(n - 1)$th acceleration. It is implicitly assumed that temperature effects may be neglected. From authors' summary

The paper is divided into five chapters: I. Kinematics of deformation; II. The stress in a body of isotropic material; III. Some results in the algebra of matrixes; IV. Scalar invariants of symmetric matrixes; V. Representations for the stress matrix in terms of kinematic matrixes. B. E. Gatewood, USA

3657. Kornfel'd, M., Methods and results of investigation of three-dimensional elasticity of matter (Bulk modulus of elasticity) (in Russian), *Usp. fiz. Nauk* **54**, 2, 315–342, Oct. 1954.

Based mainly on the work of P. W. Bridgman. The first part is a detailed description of piezometers, the second is a collection of results obtained, given as variation of the bulk modulus of elasticity as a function of pressure, with temperature as parameter (when available). Tables and curves cover gases, fluids, and solids, with special attention to phase transformation and to behavior of crystalline materials. J. Solvey, Australia

3658. Sen, B. B., Note on the solution of some problems of semi-infinite elastic solids with transverse isotropy, *Indian J. theor. Physics* **2,** 2, 87–90, Sept. 1954.

A simple method of solving problems of semi-infinite elastic solid with transverse isotropy and having symmetrical distribution of shearing stresses on the plane boundary is discussed. From author's summary

3659. Natanzon, V. Y., On a variation of the boundary condition of the plane problem of the theory of elasticity (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **98,** 27–29, 1954.

Author considers the first fundamental problem of plane elasticity for simply connected regions with the parametric representation of the boundaries in the form

$$x = x(\xi) \qquad y = y(\xi) \qquad (0 \leq \xi \leq 2\pi)$$

By replacing ξ by $u = \xi + i\eta$, one obtains a transformation of the original region into the upper semi-infinite strip $\eta \geq 0$, $0 \leq \xi = 2\pi$. Due to the multivalued character of the transformation, the actual region mapped onto the strip has a cut, so that this method can be used for the study of regions containing a single cut. The boundary condition for this type of transformation is deduced and the method of power series applied to solve one particular case. J. R. M. Radok, Australia

3660. Sokolowski, M., On certain two-dimensional problems concerning the theory of elasticity of orthotropic bodies (in Polish, with Russian and English summaries), *Arch. Mech. stos.* **6,** 65–92, 1954.

Author solves, by means of Fourier integrals, problems of plane elasticity for orthotropic media when the boundary involves straight lines. The particular cases considered are the rigid punch and the elastic beam acting on the boundary of the half plane; the concentrated force acting anywhere in the half or complete plane. J. R. M. Radok, Australia

3661. Yamada, K., On the characteristic points of bending and torsion, *Proc. 1st Japan nat. Congr. appl. Mech.*, 1951; Nat. Committee for Theor. appl. Mech., May 1952, 119–122.

Author calculates location of five characteristic points in the circular sector cross section of prismatic beam—centroid, shear center with no twist at centroid, center of twist, point with no twist when loaded at center of twist, point of zero shear stress in Saint Venant torsion problem. He shows that these points are nearly identical for certain range of sector angle ($0.3\pi <$ sector angle $< 0.8\pi$).

Paper suffers from a lack of clarity as to the physical and mathematical processes involved, mainly due to the author's inexperience with the English language and to dependence on other works for discussion of the fundamental ideas of the problem. P. Seide, USA

3662. Snowden, W., The disturbance of stress in an infinite plate by a lemniscate-shaped hole, *Brit. J. appl. Phys.* 6, 6, 220–223, June 1955.

Curvilinear coordinates are used to determine functions of a complex variable from which may be deduced the components of stress and displacement...Four cases are considered: (1) The plate is assumed to be under simple tension in any direction; (2) the plate is assumed to be in a state of uniform all-round tension; (3) it is supposed to be in a state of pure shear having any orientation to the lemniscate; and (4) the hole is assumed to be an area of compression in an otherwise undisturbed plate. In each case, expressions are obtained for the stress at the edge of the hole, and numerical values of this stress are tabulated and displayed graphically.

From author's summary by R. A. Clark, USA

3663. Shull, G. H., Thermal stresses as consequence of quasi-stationary temperature distribution (in German), *Öst. Akad. Wiss. math-nat. Kl. Anz.* **91,** 12, 183–190, 1954.

Consider a solid in which a temperature distribution is maintained which is constant when referred to uniformly moving axes. The differential equation of heat flow in these axes is quoted, as is the differential equation expressing the stress function in terms of the temperature. It is shown that, if a solution of the first equation is known, the corresponding solution of the second equation is easily derived. Solutions are found (a) for thin sheets with plane stress and Newtonian cooling from the surfaces, and (b) for an infinite three-dimensional medium.

F. R. N. Nabarro, South Africa

3664. Mura, T., Thermal strains and stresses in transient state, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 9–13.

By including thermal strains in Hooke's law, wave equations are developed for a semi-infinite block and an infinitely long cylinder with thermal transients applied to the exposed surfaces. The stresses are compared to those obtained from the usual quasi-static analysis of thermal stresses in which inertia effects are neglected. It is found that in any practical case a difference in the order of fractions of a per cent exists between the stresses from the two methods. H. Becker, USA

3665. Chapman, W. P., Are thermal stresses a problem in snow melting systems? *Heating, Piping & Air Conditioning* **27,** 6, 92–95, June 1955.

Experimental Stress Analysis

(See also Revs. 3679, 3708, 3756, 3759)

3666. Favre, H., The relation between the principal stresses in three-dimensional elasticity and its application for solids of revolution (in French), *Bull. tech. Suisse Rom.* **80,** 13, 205–210, June 1954.

Author reviews the history of Lamé's equations, $\partial\sigma_1/\partial s_1 = (\sigma_1 - \sigma_2/\rho_{12}) + (\sigma_1 - \sigma_3/\rho_{13}) - F_1$ (etc.), and the fact that their derivation depends on the existence of isostatic surfaces. Since

isostatic surfaces exist in two- but not usually in three-dimensional problems, previous applications of these equations were to the two-dimensional case (Lamé-Maxwell equations). Author shows that solids of revolution with forces symmetrical about the axis have isostatic surfaces, and he finds the modified equations for this case. These results are applied to obtain information regarding: (a) the sign of the derivative of the normal stress at the surface of a cone; (b) conditions for the normal stress along the axis of a solid of revolution to have an extremum; (c) thin shells subject to normal pressure and negligible flexure; (d) graphical procedures for separating the tensions in three-dimensional photoelasticity; (e) generalization of Mesnager's theorem (two-dimensional) to solids of revolution. Also included is a derivation of Lamé's equations.

H. D. Block, USA

3667. Dove, R. C., Strain measurement errors in materials of low modulus, *Proc. Amer. Soc. civ. Engrs.* **81,** Separ. no. 691, 1–10, May 1955.

When conventional SR-4 gages are bonded to the surfaces of materials which have a very low modulus of elasticity, the local stiffening effect of the gage may be of great importance. Not only is the recorded strain less than the value of strain which would exist if the gage were not present, but the distribution of strain in the material near the gage is altered. These effects are shown by examples worked out for a common SR-4-type gage on rubber and other materials with low E. The design and operating characteristics of several bond gages which have been developed to reduce this localized stiffening are presented.

From author's summary by R. K. Bernhard, USA

3668. Tegelaar, P., and Boiten, R. G., A new device for half-shadow compensation in photo-elasticity, *Appl. sci. Res.* (*A*) **5,** 1, 65–75, 1954.

In the frozen-stress method of three-dimensional photoelastic stress analysis, the number of fringes to be measured in a slice cut from a model seldom exceeds two. Compensation methods have to be used to obtain sufficient accuracy, and the authors suggest the use of a half-shadow device as an alternative to the extinction criterion. The half-shadow method has been applied to the Sénarmont method of compensation, in which the first quarter-wave is removed, the axes of principal stress in the model are at 45° to the polarizer, and the second quarter-wave plate has its optical plane coincident with that of the polarizer. The half-shadow device consists of an additional quarter-wave plate mounted directly after the model and divided into two parts having their optical axes at 90°. With this component in place, half-shadow effects occur as the analyzer is rotated and can be used to measure the retardation to within about ±0.03 fringe. This new development has the advantage of simplicity but would appear to reviewer to be unsuitable for application in regions of rapidly changing retardation, where the matching of the two shadows might be difficult.

A. F. C. Brown, England

3669. Nisida, M., and Hondo, M., Stress freezing photoelastic investigation of some three-dimensional stress concentration problems (I) (in Japanese), *Rep. sci. Res. Inst.* 20–40, Jan. 1954.

Experiments are made on: (1) Stress concentration by longitudinal tension or compression of a bar with two intersecting circular holes at right angles to each other and to the bar axis; (2) torsional stress concentration in cross section of a square bar with and without a longitudinal semicircular groove on each of the opposing two side surfaces; (3) stress concentration by longitudinal tension or compression of a cylindrical rod with a circumferential notch of a given angle.

Results are obtained by adopting authors' improved technique described in an earlier article.

Courtesy of Kagaku-Kenkyū-Jo Hōkoku Abstracts

Rods, Beams, Cables, Machine Elements

(See also Revs. 3638, 3706, 3710, 3714, 3715, 3717, 3731, 3747, 3945)

3670. Lessells, J. M., ed., Design data and methods, Applied Mechanics, New York, Amer. Soc. mech. Engrs., 1953, 193 pp. $4.

Ever since its first appearance, the *Journal of Applied Mechanics* has served the double task of publishing original research work and of presenting consolidated results of research in a form suitable for design applications. As the years went by, these "Design data and methods" became widely scattered over many volumes of the *Journal*. In the present book a choice of these short articles is presented in a handy form for reference. The following groups of subjects are covered: Stresses and deflections of plates, curved bars, and springs; thermal stresses; pressure vessels; stress concentration factors; buckling of columns; vibrations; balancing of rotors; gas dynamics; lubrication. The problems are chosen in view of their usefulness for mechanical engineers and the accent lies on strength of materials; fluid mechanics and vibrations take together less than half the space of the book. The many large graphs and the numerical tables will be helpful to many who want to apply the results of engineering mechanics research without having the time to penetrate into the details of the original research papers. The articles appear to be literal reproductions of those printed in the *J. appl. Mech.;* the editors have not eliminated such superseded details such as the invitation to submit discussions "until April 10, 1952," etc. Also some page references are not to pages of the book, but to those of an unknown volume of the *Journal*.

W. Flügge and I. Flügge-Lotz, USA

3671. Richter, O., Voss., R. V., and Kozer, F., Components of mechanisms with small dimensions [Bauelemente der Feinmechanik], 6th ed., edited by Kozer, F., Berlin, VEB Verlag Technik, 1954, xvi + 488 pp.

Due to the continuing demand, this book has been edited again recently. The 5th edition appeared in 1952. In order to keep the contents up to date, however, F. Kozer has made some small alterations and has added some items to the literature references, comprising only German papers.

In five different parts, connections and joining methods are described, as well as steering gears and bearings, locking and blocking means, driving means and transmissions, and speed-regulation devices.

Surely, the book will prove useful to all designers, whom it concerns.

E. Steneroth, Sweden

3672. Reswick, J. B., Dynamic loads on spur and helical-gear teeth, *Trans. ASME* **77,** 5, 635–644, July 1955.

See AMR **8,** Rev. 1618.

3673. Bishop, R. E. D., and Todd, M. A., A note on the vibration of systems containing epicyclic gears (Technical Notes), *J. roy. aero. Soc.* **59,** 532, 308–310, Apr. 1955.

3674. Henrici, P., On helical springs of finite thickness, *Quart. appl. Math.* **13,** 1, 106–110, Apr. 1955.

The stress distribution in a statically loaded, closely coiled

helical spring is investigated. The cross section of the spring is circular and is considered not small compared to the diameter of the helix. From the solution for the stress function, the stress-concentration factor is developed in terms of the reciprocal of spring index. G. V. R. Rao, USA

3675. **Kodama, M., On the coiled spring with elliptic section,** *Proc. 1st Japan nat. Congr. appl. Mech.*, 1951; Nat. Committee for Theor. appl. Mech., May 1952, 37–42.

Paper investigates the stress distribution in a close coiled circular spring of elliptic cross section. The method is based on the use of the stress function, with the resulting differential equation solved by successive approximation. The results are presented as graphs of maximum shear stress and the shear stresses at the ends of the major and minor axes. These stresses are functions of the spring radius and the ratio of the major to minor axes of the cross section. H. H. Dixon, USA

3676. **Krushkow, W. A., Calculation of dynamic stresses and strains in conveyors with chain elements** (in German), *Maschinenbautech.* **3,** 9, 475–480, Sept. 1954.

Translation from *Vestnik Maschin.* no. 10, 11–18, 1953.

3677. **Barrett, A. J., Beam strength and curvature under combined tension and bending in the plastic range,** *J. aero. Sci.* 22, 1, 71–72, Jan. 1955.

3678. **Tyler, C. M., Jr., and Rouleau, W. T., An Airy integral analysis of beam-columns with distributed axial loading that deflects with the column,** *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 297–305.

Beam-columns with distributed axial loading whose line of action did not move as the column deflected, were analyzed by C.M. Tyler and J. G. Christiano [*J. appl. Mech.* **8,** 3, 283–284, Sept. 1951; AMR **5,** Rev. 1026]. The present paper covers a more complicated case of beam columns where the axial loading deflects with the member but its line of action remains parallel to its undeflected direction. An analytical solution of the problem involves the use of Airy integral functions, their first derivatives and first integrals. Assumptions made are that the member is straight, of uniform stiffness, and that the uniformly distributed axial load balances the difference between the axial end loads. A table of the required integrals of the Airy functions needed for numerical computations is also included. Although the solution is laborious, an exact analysis is possible with this method. S. K. Ghaswala, India

3679. **Caswell, J. S., Stresses in short beams: I. Experimental analysis; II. Theoretical analysis and conclusions,** *Engineering* **178,** 4633, 4634; 625–628, 656–658, Nov. 1954.

Author has investigated stresses in centrally loaded, simply supported beams of small span-depth ratio. Experimental values of stresses were obtained by ordinary photoelastic procedures and compared with calculated stresses. Calculations were based on Stokes-Wilson theory. The difference between theoretical and observed values of maximum shear stress increase with decreasing values of span-depth ratio. Data are given for span-depth ratios varying from 5.32 to 1.06. E. K. Frankl, England

3680. **Arutyunyan, N. H., and Gulkanyan, N. O., On the center of bending of certain prismatic bars with polygonal cross section** (in Russian), *Prikl. Mat. Mekh.* **18,** 597–618, 1954.

Authors deduce exact solutions of Saint Venant's problem for bars with certain polygonal cross sections with one axis of symmetry. The solutions are obtained by considering separately rectangular subregions of the cross sections and introducing auxiliary harmonic functions which permit the subsequent joining up of the solutions in the subregions. This process leads to systems of second-order ordinary differential equations for the variable coefficients of the Fourier expansions of the component functions of the solutions. The determination of the integration constants finally leads to infinite systems of simultaneous linear equations which arise from the joining up of the solutions in the subregions. Particular cases considered are the cross sections **T, U, V,** with right angles at the corners. J. R. M. Radok, Australia

3681. **Federhofer, K., The elastically supported circular beam loaded perpendicular to its plane** (in German), "Studies in mathematics and mechanics" (Presented to R. von Mises by Friends, Colleagues, and Pupils), Academic Press, Inc., New York, 242–250, 1954.

Problem of a closed circular ring embedded in a foundation providing linear elastic restraint against deflection and rotation is considered. Fundamental differential equation of equilibrium for a beam loaded by forces perpendicular to plane of ring and torsional moments distributed along axis of ring is obtained as a special case of author's previous work [AMR **4,** Rev. 643]. For rectangular cross section where ring radius is large compared to beam width, a sixth-order linear equation with constant coefficients results. General solution for load consisting of concentrated forces is indicated. Results obtained by Volterra [AMR **5,** Rev. 1327] are a special case of author's solution.

Using principle of minimum potential energy, above differential equation is alternatively derived from the Euler equations of the variational problem of equilibrium. Direct method of solution using two parameter approximations for displacements gives good agreement with exact solution for six or more equally spaced concentrated loads. For three to six loads, good agreement is obtained for displacements, but large errors in moments occur, as would be expected. K. S. Pister, USA

3682. **Suharevskiĭ, I. V., On the problem of torsion of a composite multiconnected bar** (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **19,** 107–124, 1954.

The Saint Venant torsion problem for a compound beam (= a cylinder reinforced by the longitudinal rods) was first investigated by N. I. Muskhelishvili ["Some basic problems of the mathematical theory of elasticity," Izd. Akad. Nauk SSSR, Moscow-Leningrad, 1949, §139, 140; AMR **7,** Rev. 2099] who reduced it to the solution of an integral equation for an auxiliary function. The stresses in the beam are then determined by differentiating this function. In this paper an integral equation (2.27) is deduced which yields directly the distribution of stresses on the boundaries. The equation is solvable in Neumann's series. Paper is illustrated by an example relating to a beam with a triply connected cross section formed by three circles. The concluding paragraph contains an integral equation (7.1) for the shearing stresses on the boundaries of a composite beam whose cross section consists of n regions S_i, $i = 1, \ldots, n$, such that each S_i is wholly contained within S_{i+1}. I. S. Sokolnikoff, USA

3683. **Serman, D. I., Bending by a transverse force of an elliptic beam weakened by a longitudinal circular cylindrical cavity** (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **17,** 121–150, 1953.

Author uses N. I. Muskhelishvili's approach to set up the problem of determination of the flexure function for a doubly

connected cross section bounded by an ellipse and a circle ["Some basic problems of the mathematical theory of elasticity," Izd. Akad. Nauk SSSR, Moscow-Leningrad, 1949; AMR **7**, Rev. 2099]. Having solved the problem by function-theoretical methods, he discusses several numerical cases to reassess the validity of Jouravski's formula [Todhunter and Pearson, "A history of the theory of elasticity," vol. II, part 1, Cambridge, 1893, §939]. J. R. M. Radok, Australia

3684. Dreyfuss, M. G., Slipping of wires on the cones of prestress cables (in French, with English summary), *Ann. Ponts Chauss.* **124**, 5, 581–603, Sept./Oct. 1954.

Paper is based on the observation of difficulties caused by slipping of the wires when there is a jamming by the cone of the prestress cables.

Author gives a summary of his observations, investigates the causes of the phenomenon, and attempts to give an interpretation in simple form, based on experimental data, successively of the theory of equilibrium of symmetrical anchorage, with interposition of a double acting jack, and of the introduction of an asymmetric component in the anchorage.

Among the results which can be drawn from this analysis is an indication of the operating method to follow with regard to the jack, as well as a definition of the coefficient of safety for the slipping of the wires in a case of asymmetry which is found to be the basic factor of failure of the equilibrium of a wire.

From author's summary

3685. Schott, G. J., Thurston, F. R., and Pocock, P. J., The analysis of the structural behaviour of guyed antenna masts under wind and ice loading. Part I: Structural analysis. Part II: Wind loads, *Nat. Res. Counc. Canad., Div. mech. Engng. Rep.* MM-238, 78 pp., 56 figs., Nov. 1954.

An analytic procedure is described for computing the distribution of bending moment, shear, axial load, and deformation in the mast, and the loads in the guy wires, for a 3-level, 4-way guyed antenna mast erection subjected to wind load, ice accretion, and loads applied by an antenna installation at the head of the mast. The computational procedure is described explicitly with examples, and permits the immediate use of normal computational aids.

Part II of the report provides wind-tunnel test results on a number of mast designs with simulated ice accretion.

From authors' summary

Plates, Disks, Shells, Membranes

(See also Revs. 3666, 3670, 3710, 3714, 3716, 3717, 3912)

3686. Barton, C. S., A method for determining the stress distribution in a plate due to a uniform pressure applied over the boundary of a square hole, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 283–289.

Paper describes an approximate method of (1) replacing uniform loading on hole boundary by an equivalent loading on straight boundary of semi-infinite plate and (2) determining location of "equivalent" concentrated loads experimentally.

H. J. Grover, USA

3687. Erzin, C. Z., Solution for small deflections of rectangular plates with different edge conditions, *Bull. tech. Univ. Istanbul* **7**, 7, 50–58, 1954.

Author uses variational principle governing small deflections of thin rectangular plates under lateral loads together with superposition to obtain solutions for deflection function in form of double trigonometric series. Two cases are considered: (1) One clamped edge, others simply supported; (2) one free edge, others simply supported. Boundary conditions along the clamped or the free edge are satisfied by superposing solution for zero lateral load, and edge moments and shears necessary to balance out those resulting from solution satisfying lateral load equation and boundary conditions along the three simply supported edges. Method is essentially application of superposition principle. Use of variational principle adds no advantage.

H. J. Plass, Jr., USA

3688. Prokopov, V. K., Problem of restrained bending of a rectangular strip (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **11**, 151–160, 1952.

The difficulty of the end problem of the semi-infinite strip ($0 \leqslant x \leqslant \infty$, $-1 \leqslant y \leqslant 1$; $\sigma_y = \tau = 0$ on $y = \pm 1$; displacements or stresses are prescribed at edge $x = 0$) derives from the fact that the eigenfunctions of the problem $F_n(x, y)$ in terms of which the prescribed edge values are to be expanded have no product function representations of type $f_n(y)g_n(x)$; however, the F_n may be written as real and imaginary parts of such product functions. Fadle and Papkovich established, 15 years ago, the expressions of these $f_n g_n$ functions in the form of

$$(\cos z_n y - y \cot z_n \sin z_n y)\ [\exp(-z_n x)]$$

for even functions in y, where $\sin 2z_n + 2z_n = 0$; similar expressions hold for odd functions in y. Author writes out the lengthy expressions of the stresses and displacements that are obtainable from the real and imaginary parts of the $f_n g_n$ functions. [Author works throughout with real expressions, and it is not obvious whether his functions are the real and imaginary parts of $f_n g_n$, or two combinations of the two (a simple check would reveal this); but this is rather immaterial]. He then solves the problem of the rigidly held beam ($u = v \equiv 0$) bent by a terminal moment, using 3-point and 5-point collocation, respectively, to the $x = 0$ edge conditions. He finds that for the higher approximation the stresses are substantially larger in the corners $(x, y) = (0, \pm 1)$. (Reviewer's comment: Precise adherence to $u = v \equiv 0$ leads to infinite stresses in the corners.)

G. Horvay, USA

3689. Yu, Y.-Y., The influence of a small hole or rigid inclusion on the transverse flexure of thin plates, *Proc. second U.S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 381–387.

Using thin plate theory, author computes formulas for determining bending and twisting moments in an infinite plate in region surrounding holes or rigid inclusions of circular, elliptic, ovaloid, or nearly square shape. Plates are all assumed to be loaded in uniform bending, twisting, or shear. No lateral loads are included. Technique of conformal mapping is used, the mapping function being versatile enough to include the aforementioned shapes. Paper contains only a few numerical results, which are compared with results of previous authors.

H. J. Plass, Jr., USA

3690. Fletcher, H. J., and Thorne, C. J., Bending of thin rectangular plates, *Proc. second U.S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 389–406.

Paper contains a formulation of the solution of thin rectangular plate problems for all possible combinations of standard uniform edge conditions, edge deflections, and corner forces in terms of Fourier series expansions. Problem reduces in general to that of infinite set of algebraic equations for infinite number of Fourier coefficients. In real problems, a finite $m \times m$ block of the infinite set is selected, the size of m depending upon the problem

and the desired accuracy. In reviewer's opinion, method is practical only when high-speed computing equipment is available, as m may get too high for many cases.

H. J. Plass, Jr., USA

3691. **Szelagowski F., The influence of a bolt driven into a hole in a plate subjected to tension or bending** (in Polish, with Russian and English summaries), *Arch. Mech. stos.* **6**, 365–388, 1954.

Complex function theory is used to solve particular cases of circular holes in infinite plates with inserted, larger diameter, elastic disks. [See N. I. Muskhelishvili, "Some basic problems of the mathematical theory of elasticity," Izd. Akad. Nauk SSSR, Moscow-Leningrad, 1949; AMR **7**, Rev. 2099].

J. R. M. Radok, Australia

3692. **Donnell, L. H., A theory for thick plates,** *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech Engrs., 1955, 369–373.

Expressions for stresses and displacements in plates loaded on their faces are presented in infinite series form. The first terms are the classical thin-plate theory expressions; the higher-order terms are corrections which can be used when the plate can no longer be considered thin. Equations are derived from exact theory. The face boundary conditions are satisfied exactly, while the equilibrium, compatibility equations, and edge boundary conditions are satisfied approximately, the approximation becoming more nearly exact as more terms of the series are included.

H. J. Plass, Jr., USA

3693. **Sekiya, T., Saito, A., Ishimoto, H., and Tanaka, H., On the numerical calculation of the particular solution of the partial differential equation for plate bending** (in Japanese), *J. aero. Soc. Japan*, **1**, 1, 5–9, June 1953.

3694. **Needham, R. A., Design of round tubes for combined bending and torsion,** *Prod. Engng.* **26**, 8, 205–209, Aug. 1955.

Charts are devised which permit a direct determination of the dimensions for tubing of minimum weight for combined bending and torsion. Two examples illustrate the procedure.

E. D'Appolonia, USA

3695. **Wahl, R., On the calculation of stresses in conical drumheads** (in German), *Forsch. Geb. Ing.-Wes.* **21**, 3, 75–86, 1955.

Author develops an approximate method for the calculation of stresses and deflections in conical shells.

In the first part of the thesis a survey of the attempts to give an exact solution is given. In the second part the approximate method as developed by Bauersfeld and Geckeler (1926), and the author's method are given. The latter method is based on the principle established by Siebel and Schwaigerer that there is a close relationship in problems dealing with cylindrical and conical shells. Author develops his "cylindrical approximation" by simply solving the well-known fourth-order differential equation for the deflection of cylindrical shells [see Timoshenko, "Plates and shells," p. 392] and introducing the boundary values for a conical shell.

As an example, stresses in a conical head supported in a ring along a parallel are calculated using both approximate methods, and results are compared with the exact solution using cylindrical functions. The proposed approximate method gives better results for shells with smaller vertex angles and walls thin in comparison with the radius of curvature; in other words, for shells approaching cylindrical shapes. Good results are still obtained for angles up to 60°; for larger angles, say 90° or larger, calculated stresses are good enough for practical design, where accuracy is of secondary importance.

In the last part, author reports results of tests conducted on a conical head made of sheet steel and of 60° vertex angle. Results are in good agreement with the predicted stresses using author's approximate method.

M. Maletz, USA

3696. **Powell, E. M., and Grabowski, H. A., Drum internals and high pressure boiler design,** ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-242, 20 pp.

3697. **Rogge, B., Waffle beading for stiffening sheet metal panels,** *Prod. Engng.* **26**, 8, 171–175, Aug. 1955.

Waffle beading provides strengthening in all directions without the weight and cost of reinforcing members. Data and procedures for designing waffle-beaded panels, and variations offering exceptional strength, including high-strength lattice beading, are given.

From author's summary

3698. **Toki, G., Approximate solution of the stress and deformation of an enclosed thin ring of any shape.** (**1st Report, Against inner fluid pressure**) (in Japanese), *Trans. Japan Soc. mech. Engrs.* **21**, 103, 249–254, 1955.

3699. **Singh, K. P., Stress considerations in the design of turbine blade and disc for a small gas turbine unit,** *J. Instn. Engrs., India* **35**, 1, 111–127, Sept. 1954.

Consideration has been given first to the analytical determination of the stresses, both steady and fluctuating, followed by the actual evaluation of these stresses with respect to the properties of the materials used in the manufacturing of the component parts.

From author's summary

3700. **Grigolyuk, È. I., Equations of axially symmetric bimetallic elastic shells** (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **18**, 89–98, 1954.

This work is a continuation of the author's previous investigations on bimetallic shells reported in (1) title source **16**, 119–148, 1953; (2) **17**, 69–120, 1953; AMR **8**, Revs. 1641, 1951.

Author derives the differential equations for thin-walled axially symmetric shells subjected to arbitrary loads and heating when displacements and deformations are small. A sphere, torus, cone, cylinder, and circular plate are special cases of this general theory. Circular plates were investigated in (1), therefore here they are only briefly discussed. A cylinder, though analyzed in (2), is given here a full treatment again because the equations in (2) were arrived at in a different way and the author wants to show that the results in both papers coincide. Conical and spherical shells are discussed in some detail, but the case of toroidal shells is only outlined. Author proves that if the differential equations for a given homogeneous shell are solvable, they are also solvable for a bimetallic shell of the same shape if Poisson ratios of both layers are equal.

T. Leser, USA

3701. **Darevskiĭ, V. M., Solution of certain questions in the theory of a cylindrical shell** (in Russian), *Prikl. Mat. Mekh.* **16**, 159–194, 1952.

This paper continues the paper reviewed in AMR 5, Rev. 1342 and studies in greater detail the limiting process introduced there. Special consideration is given to the deduction of asymptotic expansions of the solutions in the neighborhood of the regions of application of the external loadings.

J. R. M. Radok, Australia

3702. İnan, M., Elastic stability of a cylindrical strip subjected to simple bending, *Bull. tech. Univ. Istanbul* **5,** 1–12, 1952.

When thin cylindrical strips are subjected to the action of simple bending, as long as the value of bending moment is smaller than a certain critical value, the elastic equilibrium of the strip becomes stable. But if the bending moment reaches that certain value, the equilibrium of the strip becomes unstable and it buckles suddenly.

The above phenomenon is studied by the use of differential equation of the equilibrium, and for the critical value of bending moment a formula is obtained. From author's summary

Buckling Problems

(See also Revs. 3670, 3717)

3703. Saeterhaug, O. H., Considerations on the buckling problem (in Norwegian, with English summary), *Tekn. Skr.* no. 11, N 3–40, 1954.

The objective of the considerations has been to arrive at the substance of the phenomenon of buckling. Starting with a thorough investigation of the deformation of a rectilinear bar, loaded at its upper free end by an eccentric and obliquely directed force, author deduces expressions leading to the limiting value of a centrally acting compressive load, causing no lateral deflection. The case of plastic deformations is considered and results are compared to those for a purely elastic material.

S. E. Kindem, Norway

3704. Nielsen, J., Eccentrically loaded wooden columns (in Danish), *Bygnstat. Medd.* **24,** 2, 39–52, 1953.

The paper gives allowable combinations of σ_N and σ_M, where σ_N and σ_M are the formally computed stresses due to normal force and bending moment, respectively. In the range where no plastic deformations occur, the formulas are checked with earlier Danish tests. C. J. Bernhardt, Norway

3705. Nielsen, J., Eccentrically loaded concrete columns (in Danish), *Bygnstat. Medd.* **24,** 2, 53–73, 1953.

If an eccentric load N is applied to a reinforced-concrete column, the eccentricity and, incidentally, the bending moment are increased due to the deflection of the column. The article deals with the determination of the increased moment M, the moment at midpoint of the undeflected column being M_0.

On the same assumption of the variation of the modulus of elasticity with the compressive stress as underlies the Rankine-Ritter formula for the allowable stress in the centrally loaded column, the expression for the increased bending moment is derived. This equation assumes, however, that no cracks have developed in the column. The formation of cracks reduces the rigidity of the column and the deflection increases progressively.

The computation of the increase of moment due to formation of cracks is based upon a comparison with beams for which the bending-deformation diagram roughly resembles a broken line. The bend denotes the cracking load, and the decrease of rigidity occurring at this point is a function of the percentage of reinforcement. The method is compared with earlier Danish tests.

From author's summary by C. J. Bernhardt, Norway

3706. Sergev, S., and Rasul, A.-R. S., Strength of trussed columns, *Trend. Engng. Univ. Wash.* **7,** 3, 21–23, 32, July 1955.

Pilot experimental investigation of columns trussed with taut guy wires attached to column ends and held away from the axis at or near midheight of column by a spreader normal to axis. Varied parameters were initial guy tension and angle between guy and column axis. Measured buckling strength ranged up to 3.5 times Euler load for corresponding untrussed column. Quality of experimental work cannot be properly evaluated without more explicit information regarding test techniques, especially the type of hinged-end fittings. Not corroborated by theoretical analysis. G. P. Fisher, USA

3707. Benthem, J. P., Step and impact loads on some nonlinear structural elements, *Nat. LuchtLab. Amsterdam Rap.* S. 455, 26 pp. and 42 figs., Apr. 1955.

Report reviews existing literature concerning transverse loads on beams deforming in the plastic range and longitudinal compressive loads on buckling columns deforming in the elastic or plastic range. The influence of the uncertainty in initial deflections on a result in a dynamic buckling test is shown.

From author's summary

3708. Broszko, M., On the solution of the basic buckling problems and their significance for the testing procedure used for buckling investigations (in German), *Bull. Acad. Polonaise Sci.* **2,** 3, 115–118, 1954.

3709. Heintzelmann, F., Buckling and bending of beam-column trains (in Spanish), *Comun. Inform. Escuela super Aerotecn. Cordoba* **3,** 4, 18 pp., 1954.

Joints and Joining Methods

(See Revs. 3691, 3747, 3751)

Structures

(See also Revs. 3642, 3648, 3653, 3682, 3685, 3688, 3704, 3705, 3743, 3780, 3782, 3783, 3940, 3943)

3710. Schwalbe, W. L., The conjugate load method in structural analysis, *J. roy. aero. Soc.* **59,** 531, 199–208, Mar. 1955.

Author outlines a method for the stress analysis of indeterminate structures which has wide application to a great variety of types of structure.

Basically the method consists of: (1) Replacing the actual structure with a geometrically similar structure consisting of members which are bars, bands, or strings connected at joints. (2) Isolating each member between joints and placing upon it the forces and couples necessary for equilibrium of the isolated member. Since these loads are related to the actual external loads, the author calls them "conjugate" loads. (3) Setting up the equations of statics. (4) Setting up the necessary deformation equations to insure continuity of the structures at the joints by equating displacements and rotations at the ends of the members which meet at a joint. (5) Solving the resulting equations of statics and deformation. The solution for shell structures involves the use of differential equations.

The method has been applied to a continuous beam, a truss with rigid joints, a pinned grid, a rigid grid, a laterally loaded plate, and a cylindrical tank of constant thickness.

K. Arnstein, USA

3711. Stüssi, P., Some principles of calculation of statically indeterminate systems (in French), *R. C. e Pubbl. Corso Perfez. costr. cemento armato,* **IV,** 1954.

Paper accents advantages of classical calculation methods by reason of their general availability compared to those developed for different special systems. Author also prefers solving linear equation systems by Gauss' algorithm. Concerning iteration

methods, he emphasizes these disadvantages: often insufficient convergence, and necessity to repeat laborious work for all load cases.

W. Mudrak, Austria

3712. Looney, C. T. G., Analysis of continuous structures by joint rotation, *Proc. Amer. Soc. civ. Engrs.* **81**, Separ. no. 679, 11 pp., May 1955.

A method of analysis is described for the determination of the moments in a continuous structure due to an unbalanced moment of unity at each joint. This method determines directly the relative stiffnesses of the members meeting at a joint restrained at the far ends by adjacent members, so that the unbalanced moment of unity can be proportioned directly between the members. Further, the carry-over moments to all the other members of the structure are determined directly.

From author's summary

3713. Bull, F. B., Steel frameworks for multi-storey buildings: A review of the development of design methods, *J. Instn. Engrs., Australia* **27**, 1/2, 27–42, Jan./Feb. 1955.

Paper outlines the developments in Britain which led to the current design codes for structural steelwork in buildings. These codes have been adopted with very little modification in the S.A.A. Interim Code 351 for the Use of Structural Steel in Buildings.

The irrationalities of the current codes when applied to multistory buildings are discussed and some suggestions are made toward revitalization of the rational method of design put forward in 1936 by the Steel Structures Research Committee.

From author's summary

3714. McComb, H. G., Jr., and Low, E. F., Jr., Tables of coefficients for the analysis of stresses about cutouts in circular semimonocoque cylinders with flexible rings, *NACA TN* 3460, 98 pp., July 1955.

Tables of coefficients are presented which facilitate the stress analysis of circular semimonocoque cylinders with cutouts by the method published in *NACA TN* 3200 [AMR **8**, Rev. 964]. When the values of two simple structural parameters are known, use of these coefficients enables shear flows and stringer loads in the neighborhood of a cutout to be calculated. The effect of bending flexibility of the rings in their planes has been taken into consideration in the computation of the coefficients. Included as a limiting case are the tables from *NACA TN* 3200 which were computed on the assumption that there is no distortion of the rings in their planes.

From authors' summary

3715. Billet, D. F., and Appleton, J. H., Flexural strength of prestressed concrete beams, *J. Amer. Concr. Inst.* **25**, 10, 837–854, June 1954.

Analytical and experimental studies on behavior and ultimate flexural strength of posttensioned, end-anchored, bonded, prestressed-concrete beams are reported. A rational analysis is developed for computing ultimate moment and steel stress at failure. Approximate expressions are given for computing ultimate steel stress for cases when the stress-strain curve for the steel reinforcement may be approximated by two straight lines.

Results of tests on 26 rectangular prestressed-concrete beams are presented. The effect of major variables—percentage of steel, amount of prestress, and concrete strength—on deflections cracking loads, and ultimate loads are studied.

Twenty-one beams failed in flexure, either by crushing of concrete after excessive elongation of reinforcement or by crushing of concrete while steel stress was in the elastic range. Three beams were nearly balanced between shear and flexural failure, and two beams failed initially in bond. Comparisons of actual ultimate moments with those computed by analytical expressions show good agreement.

From authors' summary

3716. Young, J. McH., and Landau, R. E., A rational approach to the design of deep plate girders, *Proc. Instn. civ. Engrs.* **4**, part 1, 3, 299–335, May 1955.

Paper reviews the present position of specifications relating to the design of plate girders, and deals with the buckling of plates in shear and bending. Rules are suggested for the design of web plates considering (a) elastic buckling, or (b) failure by yielding. These rules relate the permissible stresses for combined shear and bending or combined shear and direct stress. A review of experimental work is given, including the effects of continued loading after elastic buckling has occurred. Permissible stresses, with appropriate safety factors, are then discussed in more detail, and design curves showing these for various load and edge-support conditions are presented. Theoretical and empirical rules for horizontal and vertical stiffeners are compared, and recommendations for the design of these for webs governed by either elastic or yield conditions are put forward. An example from practice is worked to show the application of the suggested design procedure, and a bibliography is included.

From authors' summary

3717. Raville, M. E., Supplement to analysis of long cylinder of sandwich construction under uniform external lateral pressure, Facings of moderate and unequal thicknesses, *For. Prod. Lab. Rep., U. S. Dept. Agric.* no. 1844-A, 22 pp., 1 table, 7 figs., Feb. 1955.

The stresses in a stable cylinder and the buckling criteria of a long cylinder are determined. The elastically stable case is solved first so that the case of instability can be determined by superimposing small stresses and displacements on the former. In the core, the additional stresses are radial and shear stresses, while the additional displacements are neglected. In the facings, additional radial, tangential, and shear stresses and moments are applied, while the additional displacements consist of normal strains and changes in curvature.

By satisfying boundary conditions at the interfaces between core and skins, four displacement equations involving four parameters result. The buckling criteria are determined by equating the determinant composed of the coefficients of the parameters to zero. The critical pressures are given for certain limiting values of the elastic constants of the core and faces and of the values of the face thicknesses. Authors state without proof that the critical pressure is appreciably affected by skin thicknesses when they are as much as one fourth the core thickness. Reviewer believes that later supplements containing the solutions of cylinders of finite length will be of more value to designers.

N. C. Costakos, USA

3718. Cohen, J. S., Design of helical staircases, *Concr. constr. Engng.* **50**, 5, 181–194, May 1955.

This article gives a method of designing helical beams with a nonuniformly distributed load $w(s)$ and a nonuniformly distributed bending moment $m(s)$, both per unit length of the curve. The general differential equations of equilibrium of an element ds of the arc of any twisted curved beam related to three axes, loaded in this manner, are derived from Panayotounacos' "Analysis of any twisted curved beams loaded in any direction" and applied to the design of a staircase.

From author's summary

3719. Richart, F. E., Jr., Analysis for sheet pile retaining walls, *Proc. Amer. Soc. civ. Engrs.* **81,** Separ. no. 694, 27 pp., May 1955.

A method for analyzing sheet-pile retaining walls is developed by considering the piling to be cut at the dredge line. The shear, moment, and backfill pressures due to the material above the dredge line are computed and then are applied as loads to the portion of the pile which is embedded. This embedded length of the pile is then treated as a beam on an elastic foundation in which the stiffness of the elastic foundation is assumed to increase linearly with depth below the dredge line, and to be zero at that point. This type of foundation corresponds roughly to the behavior of sands. Graphs have been prepared which show the variations in deflection and moment in this section of the pile due to a concentrated shear or moment at the dredge line, or a uniform pressure along the embedded length. Using this information, a procedure for analyzing a chosen sheet-pile installation is presented, and the results for two examples are compared with those given by the "classical" procedures for such structures. The results of this study show the importance of the relative flexibilities of the pile section and foundation.

From author's summary

3720. Vreedenburgh, C. G. J., Stress distribution in the wall of a cylindrical water basin with constant wall thickness (in Dutch), *Ingenieur, Indonesië* **7,** 1, 1–7, Mar. 1955. [Reprint from *De Ingenieur in Ned. Indië* no. 5, 1937.]

Membrane stresses are considered only. Expressions for the stresses are derived and an example is given.

M. Botman, Holland

3721. Fialho, L., Important principles for the design of arch dams—a new method of tracing and dimensioning (in Portuguese), *Bol. Ord. Engenheiros* **4,** 1, 1–31, 9 figs., Jan. 1955.

Author introduces a new method for arch-dam design, partially theoretical and partially experimental. He describes the arch-dam development up to the most recent double curvature types, showing by examples that the main objectives have been and still are the improvement of the structural efficiency and reduction of weight. Structural improvements have been obtained by trying to have compressive stresses all over the structure, and to avoid stresses such as those due to shrinkage and to water percolation. A comparison between many dams is also given, by introducing an appropriate form coefficient, to show the reduction of weight obtained through improved structural efficiency.

Furthermore, author introduces a new method of analysis that makes the middle surface coincident with the so-called "antifunicular" surface of the applied forces (deadweight and hydrostatic pressure), in such a way that all stresses are compressive. Since the antifunicular surface is a particular case of the state of equilibrium of a membrane, it is possible to have recourse to the basic equations of the membrane theory. But the analytical determination of the antifunicular surface is a rather involved problem since it corresponds to the integration of a complex system of partial differential equations. Author introduces, therefore, an experimental method that consists in the action of a system of forces, reproducing those acting on the dam, on a membrane whose deformation reproduces just as an antifunicular surface; the author also gives a description of the experimental apparatus used. The value of the method consists in the fact that, for equal minimum allowable stresses (that can also be calculated by the method), it provides the minimum required volume of material.

S. Giorgi, Italy

3722. Howe, R. J., Design of offshore drilling structures, *Trans. ASME* **77,** 6, 827–851, Aug. 1955.

Paper is a condensation of part of the vast amount of published engineering information which applies to the design of offshore drilling and production structures. Owing to the rapid development within this field, the correlation between the theoretical and actual conditions has not been established firmly; however, additional experimental and operating information which will become available in the next few years should aid this problem considerably. The wind and wave forces which act on offshore structures are described in detail, together with the soil reactions which hold the structures in place. The internal effects such as deflections, stresses, and natural frequencies also are discussed for a number of special cases. In addition, methods for calculating the floating stability of mobile units are presented. A general classification of offshore structures is given to illustrate the relative advantages of certain general types of structures.

From author's summary

3723. Miklofsky, H. A., Bending interaction in suspension bridges, *Proc. Amer. Soc. civ. Engrs.* **81,** Separ. no. 652, 23 pp., Mar. 1955.

Author describes the procedure of obtaining a diagram called an "interaction diagram," which describes the nonlinear changes of stress and/or deflection due to a linear change of chord area or depth of the stiffening truss of a suspension bridge. The curves are drawn by analogy to similar curves which may be drawn for a simply supported beam under combined transverse load and axial tension. First part of the paper therefore treats this simpler case, and then the suspension bridge is treated. Interaction diagrams are presented and their use described in detail. In particular, an interaction diagram is drawn for the Mount Hope Suspension Bridge as an example.

The list of references contains no paper on supension bridges from publications outside the United States. Reviewer finds that more detailed information on how a variation of the flexural rigidity EJ_t of the truss affects the horizontal cable pull ($H_D + H_L$) should have been given, because it seems that the author aims at covering the total range of variation of EJ_t. The interaction diagram curves will be influenced by the variation in $H_D + H_L$, and an explanation of how this is accounted for seems to be lacking. Two misprints are to be found on page 652–659 in the line before Eq. (13) and in Eq. (14). Also there seems to be a possibility of misunderstanding in the phrasing of the first sentence in the second paragraph of the conclusion, where the stiffening truss and cable of a suspension bridge are called "a statical determinate structure."

L. N. Persen, Norway

3724. Enneper, P., Contribution to the calculation of suspension bridges. Parts I, II (in German), *Stahlbau* **23,** 6, 7; 134–137, 159–164, June, July 1954.

Analysis of the stiffening truss and the cable of a suspension bridge leads to a differential equation known as Melan's equation, the solution of which is given by the hyperbolic functions. Author states that in modern design there is a tendency to build very flexible suspension bridges, which again leads to large values of the argument of the hyperbolic function. The fact that for large values of the argument the hyperbolic functions become almost proportional to the exponential function is used by the author to simplify the calculations to a slide-rule routine. An example is given in detail. No references are given. Reviewer therefore wants to draw attention to a paper by A. Selberg ["En lettvindt beregning av hengebruer (An easy design of suspension bridges)," *Meddelelser fra Vegdirektören* no. 7, 1942], where the same problem is treated.

L. N. Persen, Norway

3725. Newmark, N. M., and Seiss, C. P., Research on highway-bridge floors at the University of Illinois, 1936–1954, *Univ. Ill. Engng. Exp. Sta. Bull.* 52, 41, 53 pp., Jan. 1955.

Paper reviews the research on highway bridge floors carried out at the University of Illinois during the period from 1936 to 1954 under the sponsorship of the Illinois Division of Highways and the Bureau of Public Roads.

The object of this research has been to determine the behavior of reinforced-concrete slabs subjected to vehicle wheel loads and to investigate the effects of the many variables encountered in different types of bridge-floor construction. The methods used have included a combination of mathematical analyses as well as extensive tests on scale-model bridges and on full-size elements of bridges.

Two types of bridges have been studied: the simple-span solid-slab bridge with integral curbs and the I-beam bridge. Tests have been made on both right and skew bridges of both types, and on both simple-span and continuous I-beam bridges. Extensive analytical and experimental studies of composite action in I-beam bridges have also been made. In addition to these studies of actual bridge types, there have been several analytical and experimental investigations of fundamental problems involved in the behavior of slabs subjected to concentrated loads.

The paper includes brief descriptions of each phase of the investigations, with references to the several publications in which the research methods and results have been reported in more detail.

From authors' summary

3726. Adams, H. W., Temperature problems of equipment in high-speed aircraft, *Trans. ASME* **77**, 5, 735–740, July 1955.

See AMR **8**, Rev. 1508.

3727. Hoff, N. J., The thermal barrier—structures, *Trans. ASME* **77**, 5, 759–763, July 1955.

See AMR **8**, Rev. 1509.

3728. Gerard, G., Some structural aspects of thermal flight, *Trans. ASME* **77**, 5, 765–771, July 1955.

See AMR **8**, Rev. 2140.

3729. Steinbacher, F. R., and Young, L., Problems in the design of aircraft subjected to high temperature, *Trans. ASME* **77**, 5, 773–778, July 1955.

See AMR **8**, Rev. 1814.

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 3652, 3653, 3746, 3751, 3760, 3766, 3775, 3776, 3789, 3791)

3730. Prager, W., Discontinuous fields of plastic stress and flow, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 21–32.

Dealing with discontinuities in a plastic-rigid continuum, author illustrates by examples the role of discontinuous velocity and stress fields. Discontinuities are grouped in two classes; in the first, they are distinguished as "weak" and "strong," the latter subdivided into "shock" or "contact discontinuities" according to whether there is or is not flux of matter across the discontinuity. Generalized stresses (e.g., bending moments) and generalized strain rates (e.g., curvature) are introduced, connected by a flow rule possessing a single yield function. If the physical equations (such as equilibrium equations) involve space and time derivatives of a field quantity (such as velocity), the discontinuity is defined as "weak" when all the derivatives of this field quantity, lower than the highest order of the corresponding derivatives appearing in the physical equations, are continuous while some of them, of the same order as those in the physical equations might be discontinuous. A "strong" discontinuity is present when even *lower* derivatives than the corresponding highest derivatives in the physical equations are discontinuous.

An analysis of a perfectly plastic plate of weak discontinuity is presented in full, followed by other similar cases of weak discontinuity. A perfectly plastic plate of strong discontinuity serves to show the analysis of this type. Various examples from literature are reviewed in terms of the above concepts and terminology.

In the second group, discontinuities are classed as either "natural" or "artificial." The discontinuous fields in the first class satisfy all equations of the theory of perfectly plastic solids, while those of the second class violate some of the fundamental equations but may furnish mathematically simple approximate descriptions of actual stress and velocity fields. This also is illustrated by examples. 54 papers are recorded in the bibliography.

Z. Karni, Israel

3731. Nagai, T., Numerical estimation of flow in beams with projected parts of strain-hardening material, *Bull. Fac. Engng. Yokohama Nat. Univ.* **3**, 41–57, Mar. 1954.

The problem considered is a plane stress or plane strain one. The material is assumed to be incompressible with a strain-hardening function of the type $\gamma = A(\tau/E)^3$, where τ and γ are octahedral shearing stress and strain, respectively. Elastic solution is obtained using finite difference. Perturbation theory is then employed to find stresses for elastoplastic case. The reviewer found the paper somewhat difficult to follow.

M. L. Pei, USA

3732. Panferov, V. M., Concentration of stresses in elasto-plastic deformations (in Russian), *Izv. Akad. Nauk Otd. tekh. Nauk* **4**, 47–66, Apr. 1954.

Plastic-elastic plane stress and plane strain in the neighborhood of notches or holes are calculated with iterative "method of elastic solutions for problems of plasticity" [Leningrad, 1946]. Author gives differential equations for approximative calculation of stresses in curvilinear coordinates. As starting values, he uses the stresses of the corresponding elastic problem. The convergence is so good that a second approximation satisfies. The calculated strain distribution in a plate with a hole is compared with measured values. Further phenomena of fracture are studied on flat specimens with hyperbolic notches.

H. Mussman, Germany

3733. Ericksen, J. L., Singular surfaces in plasticity, *J. Math. Phys.* **34**, 1, 74–79, Apr. 1955.

Some results on surfaces singular of order $n \geqslant 1$ and on the motion of such surfaces.

G. Allen, England

3734. Johnson, A. E., Frost, N. E., and Henderson, J., Plastic strain and stress relations at high temperatures. Part III, *Engineer*, Lond. **199**, 5175, 457–458, Apr. 1955.

The work described in this article is a further portion of a general research into the short-time combined stress properties of metallic alloys. It comprises tests made to determine the plastic-strain-stress relations for a 0.17%-C steel at 350 and 450 C, and an RR59 aluminum alloy at 20, 150, and 200 C, under both simple and general complex stress loading conditions. A previous paper dealt with the plastic-strain-stress relations for a magnesium alloy at 20, 50, 100, and 150 C. As in the case of the

magnesium alloy, the intent of the authors has been to explore such a range of plastic strain (1 to 2% maximum) as may reasonably be expected to occur at the commencement of a normal creep test; in this sense the short time investigation is supplementary to a combined stress-creep program. Only a selection of diagrams of results is reproduced. The full set can be examined by application to the authors. From authors' summary

3735. Clark, D. S., The behavior of metals under dynamic loading, *Trans. Amer. Soc. Metals* **46,** 34–62, 1954.

This paper (Edward de Mille Campbell Memorial Lecture) is a review of the present knowledge on the dynamic behavior of materials. The author discusses such topics as (a) elastic and plastic strain propagation, (b) dynamic stress-strain relations, or the shape of the stress-strain curve under high velocity straining, (c) strain rate effects, (d) delay of plastic strain in low-carbon steel under rapid loading, (e) preyield microstrain, (f) recovery of strength after short time loading, and (g) a discussion of the effect of dislocations on the delay of plastic yielding.

E. A. Davis, USA

3736. Onat, E. T., The plastic collapse of cylindrical shells under axially symmetrical loading, *Quart. appl. Math.* **13,** 1, 63–72, Apr. 1955.

Assuming a material which obeys Tresca's yield condition and the associated flow rule, author obtains a yield surface in a stress resultant space for the special problem considered. Points inside this yield surface correspond to safe combinations of axial force N_x, N_φ, and M_x, bending moment; points on the surface correspond to critical combinations of these stress resultants.

At a point on this yield surface, a normal vector has components $N_0\epsilon_x$, $N_0\epsilon_\varphi$ and $M_0\kappa$, where ϵ_x, ϵ_φ, and κ are the principal strain rates and the rate of change of curvature, $N_0 = \sigma_0 h$ and $M_0 = \sigma_0 h^2/4$. The special conditions which these components satisfy along an edge and at a corner are also given.

Using an approximation to the yield curve, author obtains a solution for a cylinder free at one end and built in at the other. The solution obtained satisfies equilibrium, compatibility, yield, normality, and boundary conditions.

The method described can be employed to solve the plastic collapse problem for the general shell. S. F. Borg, USA

3737. Rigby, B. J., Stress relaxation of wool fibres in water at strains of 5–20 per cent, *Austral. J. Phys.* **8,** 1, 176–183, Mar. 1955.

A study has been made of the stress relaxation at fixed longitudinal strains of wool fibers immersed in water, in the post-yield region of their load-strain curves. The fibers were extended at controlled rates up to predetermined strains, particular attention being paid to the first few minutes of the subsequent stress relaxation. It was found that the relaxation curves so obtained could be represented by a sum of one, two, or three negative exponentials, which could, in general, be simplified into two main processes: (a) a relatively fast relaxation of stress occurring in about the first 60 sec, and (b) a much slower relaxation. The activation energy of the fast process was found to be approximately 5 kcal/mol. Attempts to calculate activation energies for the slow process showed that the term corresponding to the energy was temperature-dependent. Over the range 10–50 C, the values of this term were found to increase from about 22 to 27 kcal/mol. The fast and slow processes are respectively ascribed to the breakdown of weaker and stronger types of cross-linking bonds in the keratin. From author's summary

3738. Papadakis, M., Rheology of suspensions of cement (in French), *Rev. Mater. Constr.* **476,** 121–137, May 1955.

Tests are described which appear to justify the hypothesis of the assimilation of cement suspensions to a class of bodies conforming with the simple rheological concept: plastic fluid, or Bingham's fluid.

Notes are given on the theory of the coaxial cylinder type and variable flow rate viscosimeter, together with the practical setting up of the apparatus.

Plastification of cement suspensions is then dealt with. Plastification produced by the admixture of fine products (clay or Bentonite) and by chemical agents are compared, and basic differences between them are emphasized.

The interest of rheological measuring methods is brought out, in particular in its application to cement injections.

From author's summary

3739. Watson, S. J., Short-time creep-relaxation tests. Effect of methods of loading, *Engineering* **179,** 4658, 565–566, May 1955.

3740. Draper, J. H. M., Creep-relaxation testing. Tests at constant strain and decreasing load, *Engineering* **179,** 4658, 564–565, May 1955.

3741. Schultz-Grunow, F., New results and methods in rheology (in German), *ZVDI* **97,** 14, 409–416, May 1955.

This is an introduction to the general concepts of rheology leading to a review of some recent developments.

M. Reiner, Israel

Failure, Mechanics of Solid State

(See also Revs. 3591, 3726, 3727, 3728, 3729, 3732, 3734, 3736, 3739, 3740, 3765, 3769, 3788, 3944)

3742. Wells, A. A., The geometrical size effect in notch brittle fracture, *N. E. Cst. Instn. Engrs. Ship. Trans.* **71,** part 6, 277–290, Apr. 1955.

Experiments support geometrical size effect of suppression of notch brittle fracture in small slow bend specimens. This fracture size effect is due to absence of sufficient elastic energy for propagation.

Elastic energy for propagation is estimated by measuring amplitude of temperature wave with a special four-channel catenary string galvanometer. W. Soete, Belgium

3743. Holzhauer, G., The question of safety in construction elements for high steam temperatures (in German), *Brennstoff-Warme-Kraft* **6,** 6, 219–223, June 1954.

Author emphasizes that high-temperature design must be based on continuous creep and failure in finite time. Numerous case histories are presented which show how closely actual temperatures in critical boiler elements can be calculated and what effect higher temperatures have on these elements. Author points out the critical locations that should be watched closely, and discusses the importance of measuring creep strain at these locations. D. Kececioglu, USA

3744. Hundy, B. B., Strain-aging in 70:30 brass, *J. Inst. Metals* **83,** 115–116, 1954–55.

Strain-aging has been observed during tensile tests on 70:30 brass strip. The results are interpreted in terms of Cottrell's theory. From author's summary

3745. Stulen, F. B., and Cummings, H. N., A failure criterion for multi-axial fatigue stresses, *Proc. ASTM* **54,** 822–835, 1954.

Theory is based on the assumption that fatigue failure is associated with alternating slip on critical shear planes and that critical shear stress is a linear function of normal stress on the critical planes. Methods are proposed to allow for anisotropy and effect of steady stresses superimposed on vibratory stresses.

Theory was tested against 270 *S-N* curves for bending, torsion, combined bending and torsion, on smooth and notched specimens, for both ductile and brittle metals. Comparisons are made with distortion energy and maximum shear theories.

Reviewer believes that, in light of recent evidence showing extent of scatter in fatigue data, some statistical approach to the determination of the fatigue parameters present in the mathematical statement of this theory is essential, but that this theory is an important contribution to the study of fatigue under combined stresses. D. E. Hardenbergh, USA

3746. Henry, D. L., A theory of fatigue damage accumulation in steel, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Paper 54—A-77, 12 pp.

At present, there is no theoretical method for predicting the change in the endurance limit of steel specimens subjected to various numbers of cycles of overstressing at different stress levels. The theoretical and most of the experimental work accomplished thus far has been concerned with studying the change in endurance life at some stress level resulting from the accumulation of various amounts of overstressing at other stress levels. It is the purpose of this paper to present a simple theoretical model for predicting the change in endurance limit resulting from the accumulation of overstressing cycles at moderate levels of overstress and for moderate degrees of fatigue damage. Review of the literature indicates that it is reasonable to assume that fatigue damage occurring prior to the formation of a visible crack is equivalent to an increase in a stress-concentration factor associated with the particular defect in the specimen which will form the fatigue nucleus. The application of simple notch-factor concepts and the use of an empirical formula for the *S-N* curve for steel resulted in an equation for predicting the change in the *S-N* curve when specimens are subjected to overstressing histories producing moderate amounts of fatigue damage.

From author's summary

3747. Weibull, W., Static strength and fatigue properties of threaded bolts, *Aero. Res. Inst. Sweden Rep.* no. 59, 25 pp., May 1955.

The tensile strength of 497 double screw joints has been determined and its distribution has been found to be neither normal nor log-normal. An exponential distribution function previously used by the author fits the data reasonably well.

The fatigue lifetimes of 417 of the same joints have been measured at five stress levels. The distributions at the lower levels consist of two components. If the upper (with regard to life) components are neglected, all the remaining data may be pooled into one distribution, the statistics of which have been computed. The statistical fatigue properties have been condensed into one single equation, the *P-S-N* equation.

From author's summary

3748. Weibull, W., Scatter in fatigue life of notched plate specimens of 24S-T Alclad, *SAAB Aircr. Co. Linköping TN* 32, 17 pp., May 1955.

The fatigue lifetimes of 1088 flat 24S-T Alclad specimens with two drilled holes have been determined at a tension pulsating between 14 kg sq mm and zero. The material was taken from 19 plates of two different origins. There was a marked difference in fatigue properties of the different plates and also between longitudinal and transversal specimens in regard to the direction of rolling, but an average distribution function for each source was obtainable. The shortest life, even in a not very large sample, may be expected to be about $^1/_3$ of the average life. From author's summary

3749. Carl, R. A., and Wegeng, T. J., Investigations concerning the fatigue of aircraft structures, *Proc. ASTM* 54, 903–925, 1954.

3750. Koziarski, J., Fatigue aspects in aircraft welding design, *Welding J.* **34,** 5, 446–458, May 1955.

3751. Mann, J. Y., compiled by, Bibliography on the fatigue of materials, components and structures. Vol. 1, 1843–1938, Aero. Res. Labs., Melbourne, Austral., 288 pp., Aug. 1954.

3752. Betteridge, W., Sachs, K., and Lewis, H., The influence of vanadium pentoxide on the high-temperature scaling of heat-resisting alloys, *J. Inst. Petrol.* **41,** 377, 170–180, 1955.

Material Test Techniques

3753. Rohner, F., Nondestructive testing of materials and parts (in German), *Schweiz. Arch.* **20,** 11, 371–373, Nov. 1954.

Progress in nondestructive testing of materials and parts since 1948 is reviewed under four main headings: radiography, electric-induction tests, magnetic methods, ultrasonic testing. Special attention is paid to radiography with radioactive isotopes.

From author's summary

3754. Yoshizawa, T., On the measurement of Shore hardness of sheet metals (in Japanese), *Trans. Japan Soc. mech. Engrs.* **21,** 103, 243–248, 1955.

Although this is not its proper application, the Shore scleroscope is often used for the commercial measurement of hardnesses of sheet metals, because of its character. The present report discusses the influence of the hardness of the anvil of the scleroscope and the way of mounting specimens on the measured value of the hardness of a thin plate as well as the variation of the hardness number of a laminated specimen with its thickness.

The results of this investigation are:

(1) The hardness of a thin metallic specimen should be measured on a single sheet, unless the specimen is laminated to a certain thickness.

(2) If the hardness is measured in the way mentioned in (1), the hardness value given by the instrument remains approximately constant independent of the hardness of the anvil, if the anvil is only harder than the specimen.

(3) Thus the indicated value of the hardness of sheet metals may be influenced by the hardness of the anvil, but as it does not noticeably change with the variation of the hardness of the anvil, this value may be used for commercial purposes.

From author's summary

3755. Reynolds, M. B., The determination of the elastic constants of metals by the ultrasonic pulse technique, *Trans. Amer. Soc. Metals* **45,** 839–853, 1953.

The ultrasonic pulse technique has been used to determine Young's modulus, shear modulus, and Poisson ratio of the following polycrystalline metals: beryllium, columbium, zirconium,

titanium, vanadium, thorium, uranium, alpha brass, and type 347 stainless steel.

The relationships between elastic wave velocities and elastic constants are given for the case of an isotropic solid. Elastic wave propagation and reflection are treated briefly. The ultrasonic pulse technique is described, including the internal reflection method of Hughes for determination of the shear wave velocity in cylindrical specimens.

The ultrasonic pulse apparatus is described and the computation of wave velocities illustrated.

The elastic moduli obtained are tabulated and discussed. A comparison is made with data from the literature, where such data exist. For the metals columbium, titanium, thorium, and vanadium, it is believed that all three elastic constants have not been previously reported. From author's summary

3756. Wells, W. M., Jr., and Hansen, R. J., Machine for static and dynamic testing of slabs, *Proc. Soc. exp. Stress Anal.* **11,** 1, 213–220, 1953.

A testing machine which will produce a controlled, uniformly applied static or impulsive load to a test panel as large as three feet square and eight inches thick has been designed and constructed. This machine was built for use in an experimental program on the behavior of structural elements under conditions simulating loading applied to structures that are subjected to atomic blast.

The load applied by the machine may vary in magnitude from a fraction of one psi to 250 psi. The impulsive load may be applied in 0.003 second, and may be varied in duration from a few hundredths of one second to many seconds. Instrumentation for the measurement of pressure, deflection, acceleration, and strain was developed. Typical test results are presented.

From authors' summary

3757. Johnson, E. E., and Goldhammer, B. F., The determination of the critical load of a column or stiffened panel in compression by the vibration method, *Proc. Soc. exp. Stress. Anal.* **11,** 1, 221–232, 1953.

See AMR **5,** Rev. 2798.

3758. Chefdeville, J., Resistance of concrete to compression by the method of measuring dynamic modulus of elasticity (in French), *Ann. Inst. tech. Bât. Trav. publics* nos. 91–92, 739–784, July–Aug. 1955.

In this study, the author, by means of laboratory tests under closely defined conditions, is able to define accurately the empirical relationship between the dynamic modulus of elasticity and the resistance to compression obtained by crushing cubes of concrete.

Different cements were tested and a large range of resistances was examined, varying from 11.3 to 85.3 psi. To obtain this range, tests were carried out on concretes of ages varying from 3 to 200 days.

From this research it is possible to deduce the value of the relation between modulus and resistance, and it is also possible to know with what precision the compression resistance may be deduced by the nondestructive measurement of the modulus on concrete structures.

The whole range of tests has made it possible to determine the evolution of the dynamic modulus of elasticity and the dynamic Poisson coefficient with the age of the concrete and, consequently, the rate of hardening of concretes made from the different cements examined. From author's summary

3759. Starkey, W. L., and Marco, S. M., A new fatigue-testing machine capable of inducing complex stress-time relationships in its specimen, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-80, 11 pp.

A fatigue-testing machine has been designed and constructed to serve as a research tool for investigating the effects of multi-harmonic complex uniaxial stresses on the endurance lives of metals. The machine induces in its specimen a complex stress pattern composed of the superposition of fundamental and second-harmonic sinusoidal stress-time waves. Synthesis of component stress waves is achieved by the action of independently controlled cam-operated plungers on a common volume of hydraulic fluid. The resulting time-periodic pressure acts on a piston to which the specimen is attached.

From authors' summary

3760. Kesler, C. E., Effect of speed of testing on flexural fatigue strength of plain concrete, *Nat. Res. Counc. Highway Res. Bd. Proc. 32nd Ann. Meet.,* 251–258, 1953.

Several specimens failed after sustaining over 1 million cycles of stress. Few data are available in this field from tests that have been carried beyond 1 million cycles. Even though these tests were conducted to a maximum of 10 million cycles of stress, no specimen failed at a stress less than 55% of the static strength. Nevertheless, there is no indication that an endurance limit exists.

The results of the tests indicate that the speed of testing, within the range investigated, has little effect, if any, on the fatigue strength and life of concrete, assuming the concrete to be of strength normally used in construction. This conclusion must be limited to concretes made of sound aggregates. However, as a word of caution, it should be pointed out that other factors, such as moisture content, over which no control was exerted in these tests, might have had as great an influence on these results as the speed of testing. Future tests are contemplated to study the influence of these and other variables. From author's summary

3761. Gofman, S. I., A method for determining of mechanical properties of test specimens for springs (in Russian), *Zh. tekh. Fiz.* **24,** 4, 722–728, Apr. 1954.

3762. Olleman, R. D., Wessel, E. T., and Hull, F. C., A study of factors controlling strength in the torsion test, *Trans. Amer. Soc. Metals* **46,** 87–99, 1954.

The factors determining strength in the static torsion test have been studied over a wide range of tempered hardnesses in a 1.0% carbon, 5.0% chromium, 1.0% molybdenum, 0.2% vanadium tool steel. Conclusions are based on correlation of measured mechanical properties with the appearance of the fracture surfaces. It was found that failure at low hardnesses is controlled by shear fracture strength and at high hardnesses by tensile fracture strength. Tensile fracture strength is determined by stress-raising imperfections and by the sensitivity of the steel to these stress raisers. The sensitivity factor is strongly related to the presence of retained austenite. The weakening effect of the retained austenite may be reduced by plastic deformation which causes transformation of the austenite.

From authors' summary

3763. Richards, C. W., Size effect in the tension test of mild steel, *Proc. ASTM* **54,** 995–1002, 1954.

In 1931 Fujio Nakanishi made his well-known report of a yield point in bending raised by 50% above that in tension, using rectangular beams of mild steel. The presence of a size effect seems to offer the only satisfactory explanation for this and subsequent

widely divergent results that have been reported over the past twenty-odd years. The investigation described herein has for its object the development of an adequate theoretical basis for such a size effect and the testing of its validity by experiment. Due to a similarity between the discontinuous yielding of mild steel and brittle fracture, Weibull's statistical theory of the strength of materials has been adapted to fit the new problem. Because of its statistical nature, large numbers of tests are required to check the theory. The present report covers the first series of tests, which were made in tension. The experimental results obtained demonstrate a definite dependence of the upper yield point of mild steel on specimen size. Thus the conclusion is reached that, in the tension test of mild steel, the specimen size is one of the important variables. From author's summary

3764. Schwartzbart, H., and Sheehan, J. P., Effect of specimen size on notched bar impact properties of quenched-and-tempered steels, *Proc. ASTM* **54,** 939–952, 1954.

The impact properties of 8600 steel at four carbon levels, 5140, and 4140, quenched and tempered at temperatures from 400 to 1200 F, have been determined, using three sizes of impact specimens geometrically similar except for notch radius which was held constant. The linear scale factors of the specimen sizes investigated were 1:2:3.3 with the standard Charpy specimen having the scale factor of 2.

The conclusions are as follows:

(1) Maximum impact energy per unit fracture area (area under the notch) is relatively independent of specimen size at tempering temperatures from 400 F to 700–800 F, but is dependent on specimen size at tempering temperatures between 700–800 F and 1200 F. In this region, maximum impact strength is higher the larger the specimen dimensions.

(2) Maximum impact energy per unit volume decreases with increasing specimen size over the entire range of tempering temperatures investigated.

(3) A distinct size effect is exhibited in transition temperature; the transition temperatures of the small specimens were considerably lower than those of the standard size specimens, which were in turn generally lower than those of the large specimens, especially at high hardnesses.

(4) For the 8600 series of steel, transition temperature increases with carbon content. From authors' summary

Mechanical Properties of Specific Materials

(See also Revs. 3657, 3734, 3737, 3738, 3746, 3748, 3754, 3758, 3760, 3763, 3793, 3897, 3957)

⊛3765. Mondolfo, L. F., and Zmeskal, O., Engineering metallurgy, New York, McGraw-Hill Book Co., Inc., 1955, ix + 382 pp. **$7.50.**

Book presents a broad view of metallurgical science with emphasis on physical metallurgy and constitution. It is intended to serve as a college text in teaching metallurgy to students whose chief interests lie in some other field, for example, mechanical engineering. Authors discuss numerous branches of the subject from extraction through corrosion and include the physics of metals, equilibrium diagrams, casting, working, heat treatment, etc. Enough detail is provided to make the work useful to the practicing metallurgist.

Theoretical aspects are stressed in order to afford a sound basis for understanding practical operations. Sets of questions and problems appear at the end of each chapter, and they are designed to illustrate the principles discussed. Also, lists of standard reference books on metallurgy and related matters are appended to the chapters. These are mostly late publications of American origin.

Tables of the more common alloys, both ferrous and nonferrous, used for engineering purposes are given together with values for some mechanical properties. Minor and rare metals are treated briefly. Illustrations are numerous and well chosen.

R. J. Anderson, USA

3766. Westbrook, J. H., Temperature dependence of the hardness of pure metals, *Trans. Amer. Soc. Metals* **45,** 221–243, 1953.

3767. Lozinskiĭ, M. G., and Fedotov, S. G., Variation of hardness of pure metals during heating (in Russian), *Izv. Akad. Nauk Otd. tekh. Nauk* **4,** 80–85, Apr. 1954.

3768. Roach, A. E., and Hunnicutt, R. P., Scoring characteristics of thirty-eight different elemental metals on high-speed sliding contact with steel, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-61, 14 pp.

3769. Clauss, F. J., Garrett, F. B., and Weeton, J. W., Effect of some selected heat treatments on the operating life of cast HS-21 turbine blades, *NACA TN* 3512, 39 pp., July 1955.

3770. Chatterjee, G. P., Development of blade materials for the gas turbine, *J. Instn. Engrs., India* **35,** 1, 127–137, Sept. 1954.

3771. Nippes, E. E., Wawrousek, H., and Fleischmann, W. L., Some properties of the heat-affected zone in arc-welded type 347 stainless steel, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-57, 22 pp.

3772. Wells, C., Russell, J. V., and Poole, S. W., Effect of composition on transverse mechanical properties of steel, *Trans. Amer. Soc. Metals,* **46,** 129–156, 1954.

Eleven basic electric-furnace production heats, varying from 15 to 70 tons weight, representing a series of alloy steel base compositions were utilized for this investigation. The composition of a series of ingots from each of these heats was modified by ingot mold additions of carbon, silicon, nickel, chromium, molybdenum, boron, and rare earths, the latter as metals or oxides. The hot-rolled or forged ingot product was quenched and tempered to various tensile strength levels, generally in the form of 1-in. thick sections cut from a 7-in. diam round in order to evaluate (a) the effect of carbon; (b) the effects of silicon, nickel, chromium, and molybdenum; (c) the effects of boron added as Grainal no. 1, no. 79, and ferroboron; (d) the effects of rare earths added as metals or oxides; and (e) the effect of combinations of boron, rare earths, and silicon on transverse tensile strength, transverse reduction of area (RAT), and transverse impact quality. The results of this preliminary investigation are presented as a comparison of these properties as they would be expected to be at identical strengths in the range of 150,000 to 185,000 psi. From authors' summary

3773. Bardgett, W. E., and Clark, C. L., Comparative high-temperature properties of British and American steels, *Inst. mech. Engrs. Proc.* **168,** 16, 465–469 + 8 plates, 1954.

Some rather substantial differences are found in creep data on similar steels published in various countries. In view of the importance of these differences in relation to design stresses, arrangements were made for an exchange of specimens between The Timken Roller Bearing Co., of Ohio, and The United Steel Companies in order to determine whether the results from the two

laboratories, on the same steel, would be in agreement, and to compare the creep resistance of selected steels.

Five representative high-temperature steels were chosen comprising three commonly used ferritic steels and two austenitic steels. For each composition, four creep curves were obtained, two by each laboratory. Stress, temperature, and time adopted in the tests in the two laboratories were the same and no attempt was made at standardization of test procedure. A high degree of reproducibility was shown by the test results for the two laboratories on the ferritic steels, but those on the austenitic steels showed generally substantial differences.

Only two British steels, both of ferritic type, showed similar creep behavior compared with the corresponding American steels; the remaining three steels show appreciable differences, which are discussed. From authors' summary

3774. Fast, J. D., Investigation ot the resistance to shock of iron and steel (in Spanish), *Cienc. y Tecn.* **120,** 604, 21–32, Jan. 1954.

Article reviews the execution and significance of the notched-bar impact test, the elementary concepts of stress and fracture, and describes original measurements by means of which the impact value of pure iron is determined as a function of temperature. The effect thereon of oxygen, carbon, and nitrogen is investigated. From author's summary

3775. Port, J. H., and Blank, A. I., The creep characteristics of copper-nickel alloys at 300, 400, and 500 F, *Proc. ASTM* **54,** 1038–1049, 1954.

3776. Manjoine, M. J., and Mudge, W. L., Jr., Creep properties of annealed unalloyed zirconium, *Proc. ASTM* **54,** 1050–1067, 1954.

3777. Heimerl, G. J., and Inge, J. E., Tensile properties of 7075-T6 and 2024-T3 aluminum-alloy sheet heated at uniform temperature rates under constant load, *NACA TN* 3462, 46 pp., July 1955.

3778. Mallory, H. D., Propagation of shock waves in aluminum, *J. appl. Phys.* **26,** 5, 555–559, May 1955.

The velocity of shock waves in aluminum and the associated translational motions, produced by metal-metal impact, have been determined by an electrical contact technique. The results obtained have been used to evaluate an equation of state for the metal. From author's summary

3779. Jaeger, H. E., Aluminum in shipbuilding, *Inter. Shipbldg. Progr.* **2,** 11, 319–350, 1955.

3780. Liska, J. A., Tests of extruded magnesium cargo flooring for aircraft, *For. Prod. Lab. Rep., U. S. Dept. Agric.* 1550-I, 49 pp., Oct. 1954.

3781. Johnson, A. E., Jr., Mechanical properties at room temperature of four cermets of tungsten carbide with cobalt binder, *NACA TN* 3309, 16 pp., Dec. 1954.

3782. Vinberg, H. A., Compressive strength of lightweight concrete brick walls (in Swedish, with English summary), *Instn. Byggnadsst. Medd.* no. 13, 95 pp., 1953.

Paper gives a detailed report of an experimental study of the different factors which affect the strength of Siporex lightweight concrete brick walls. Tests were made on 46 brick walls of full size. The discussion of the results includes brick properties, brick-work dimensions, properties of the joints, quality of the mortar, and the type of loading. A scheme for further tests is discussed.

The report should be of special interest for all working in this field. C. J. Bernhardt, Norway

3783. Dietz, A. G. H., Physical and engineering properties of plastics, *J. Boston Soc. civ. Engrs.* **42,** 2, 134–157, Apr. 1955.

Author reviews properties of plastic materials from standpoint of their use in building construction. Subjects covered include: current applications in building; types of plastics; mechanical properties such as tensile strength and modulus, creep behavior, thermal expansivity, and conductivity, and temperature resistance, comparison being made with other building materials such as metals, concrete, and wood; and weathering and corrosion resistance.

Some important fabrication variables such as fillers, plasticizers, orientation, reinforcing agents, laminating, and sandwich construction are also discussed. Trends in building construction are outlined, for example, toward large shop-fabricated panels, open-type walls, and luminous ceilings. Author suggests how plastics, because of their versatility of design and varied properties, might be profitably used. B. M. Axilrod, USA

Mechanics of Forming and Cutting

3784. Vieregge, G., Temperature field and heat balance in chip-forming cutting (in German), *Werkstatt u. Betrieb* **88,** 5, 227–230, May 1955.

Mathematical calculation of heat distribution in machining operations makes it possible to survey the individual spheres of influence and their mutual importance. Article deals especially with shearing heat and its influence upon temperature of chips and workpiece. The results of the detailed method for ascertaining the temperature range with movable heat source agree very well with those of other methods. Their deviations from tests carried out are understandably explained.

From author's summary by R. R. Hanson, Sweden

3785. Ling, F. F., and Saibel, E., Interaction of friction and temperature at the chip-tool interface in metal machining, *Trans. ASME* **77,** 5, 693–700, July 1955.

See AMR **8,** Rev. 1696.

3786. Morton, I. S., and Tourret, R., Mechanical testing of cutting oils (Symposium on metal-working oils. Part I, Metal cutting), *J. Inst. Petrol.* **40,** 369, 261–269, Sept. 1954.

The properties of a good cutting fluid are discussed, and drilling, tapping, and turning tests are performed to evaluate fluids. It was found that turning tests gave similar picture to drilling tests, but the results were less reproducible. Tests with small ($^1/_4$-in. diam) drills gave results similar to those for larger ($^5/_8$-in. diam) drills. A very wide scatter in the tapping results was obtained. Little correlation between bench tests and cutting tests was evident and little correlation between cutting forces and tool life.

It was found that, in general, when tool life was improved by a fluid the finish was impaired.

No correlation between tool life and percentage of chlorine or sulfur present was found, or even percentage of sulfur released at 100 C or 200 C. Straight oils were found to be poor lubricants, but rape oil was found to be an important additive. Particular chlorinated hydrocarbons were found to have an adverse action

on tool life. Certain sulfurized fatty oils were found superior to sulfurized fatty oils containing chlorine. The nature of the base oil was found to influence the action of an additive in an important way. M. C. Shaw, USA

3787. **Bowden, F. P., and Tabor, D., Mechanism of friction and lubrication in metal-working (Symposium on metal-working oils. Part I, Metal cutting),** *J. Inst. Petrol.* **40**, 369, 243–253, Sept. 1954.

Authors review theory of friction and boundary lubrication and give examples of how the results of fundamental studies may be applied to metal working, including the properties of diamond as a tool or die material, the properties and action of metal soaps as lubricants, the action of fluid additives to form sulfur and chlorine films. The use of gases in cutting as a means of separating the cooling and lubricating actions of a fluid is suggested. A few cutting experiments are described, including tests with a molybdenum tool. M. C. Shaw, USA

3788. **Schultink, L., Spier, H., and Wagt, A. v. d., The abrasion of diamond dies,** *Appl. sci. Res. (A)* **5**, 1, 1–11, 1954.

Diamond dies used in wire-drawing often experience changes in the shape of the bore from round to oval, to square, or even to triangular. The author attempts to explain this phenomenon. He theorizes that it is easier for abrasion to occur along certain faces of the crystalline structure. He reasons why, because of its lattice configuration, a die drilled perpendicular to its cube face tends into a square section, while one drilled perpendicular to its dodecahedral face tends into an oval shape and, if drilled perpendicular to the octahedral face, into a triangular opening. To check the validity of the suggested explanation a special oxygen-combustion process of etching diamond faces was developed. Electron photomicrographs of the etched faces illustrate effectively the abrading possibilities of diamond faces as previously theorized. In addition, abrasion rates determined for diamonds from the same geographic location revealed, as does the theory, that the smallest wear is experienced with stones drilled along the threefold axis. J. P. Vidosic, USA

3789. **Yamada, Y., Theory of formability testing of sheet metals,** *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 51–56.

The stress-strain relations in forming hollow bodies of revolution are analyzed in relation to the stress-strain diagram for a tensile test. The tensile stress-strain diagram is expressed by an empirical equation involving the tensile strength and a strain-hardening exponent. It is assumed that, for a specific material, the octahedral stress depends only upon the octahedral strain.

The applications are principally to the deep drawing operation. Various parameter ratios of stress, strain, and some of the principal dimensions are computed and plotted against the reduction of diameter in the drawing operation. W. Schroeder, USA

3790. **McEvily, A. J., Jr., Analysis of ear formation in deep-drawn cups,** *NACA TN* 3439, 7 pp., May 1955.

A review of the literature on deep drawing and on anisotropy of metals indicates that no direct correlation has been established between the number and location of the ears on deep-drawn cups and the preferred crystallographic orientation of the blank material. In the present paper, a method for predicting earing behavior is proposed which is based on the plastic properties of single crystals and a knowledge of the preferred orientation of the blank material. The proposed method of prediction is in satisfactory agreement with reported experimental results.

From author's summary

3791. **Frisch, J., Contribution to the knowledge of pressure measurements during metal deformation,** *Trans. ASME* **77**, 4, 509–513, May 1955.

Two pressure-measuring devices using SR-4 strain gages and steel pins of $^1/_8$-in. and $^1/_4$-in. diam, respectively, were inserted in the wall of an extrusion cylinder. During the extrusion of commercially pure lead the mean pressure and radial wall stresses were measured and found to be in close agreement with the calculated values. The calibration of the instruments showed considerable difference between the curves obtained from dead-weight calibration and those found from a simulation of the extrusion process. From author's summary

3792. **Ericsson, L.-E., Käufl, J., and Olson, C. O., Apparatus for semi-automatic transfer of length-represented data to punched cards and charts,** *Aero. Res. Inst. Sweden Rep.* 56, 12 pp., Apr. 1955.

An apparatus for semiautomatic evaluation of length-represented data has been designed. The data are projected to suitable scale on a horizontal movable plate, covered by a chart sheet. A pointer is carried over the plate and, when it is aligned with the measuring point, a switch on the pointer is actuated causing the measurement to be registered simultaneously in a punched card and on the chart. The apparatus has been in use since the end of 1952 and has proved satisfactory.

From authors' summary

3793. **Ashburn, A., How to work titanium and its alloys,** *Amer. Machinist* **99**, 17, 89–104, Aug. 1955.

A comprehensive summary of where titanium stands today, in production and use, the properties that can be expected, and the current practice in heat treating, machining, forming, casting, welding, cleaning, and finishing. From author's summary

Hydraulics; Cavitation; Transport

(See also Revs. 3720, 3796, 3814, 3815, 3846, 3916, 3946)

3794. **Souczek, E., Calculation of hydrofoils** (in German), *Öst. Ing.-Arch.* **8**, 2/3, 214–221, 1954.

Author applies the theory of the "lifting wing in nonhomogeneous flow" to the plane problem of the underwater lifting surface. The marginal condition of the surface of the water is approximately met by the horizontal speed on that surface being kept constant by the reflection of the profile chord with its eddy distribution, whereby the direction of rotation remains unaltered.

The influence of the reflected eddy distribution on the profile is replaced by a single eddy (whirl) in the center of circulation. In consequence of this simplification, the method of calculation remains surveyable and sufficiently precise so that the formulas obtained are simple, provided that the first approximation is considered sufficient.

From author's summary by P. F. Maeder, USA

3795. **Cummins, W. E., Hydrodynamic forces and moments acting on a slender body of revolution moving under a regular train of waves,** *David W. Taylor Mod. Basin Rep.* no. 910, vi + 33 pp., 1954.

The hydrodynamical force and moment acting on a slender body of revolution are found for the case in which the body is moving with constant linear velocity under a sinusoidal train of waves oblique to the course of the body. The analysis makes use of a representation of the body by a system of singularities, and the dynamic effects are evaluated by means of the methods developed by the author in *Taylor Mod. Basin Rep.* 780, 1953 [see

AMR 7, Rev. 840]. The force and moment are given explicitly as functions of the sectional-area curve of the body. Three illustrative examples are worked out, including a case in which there is no analytical expression available for the sectional-area curve. The results constitute a linearized approximation. They are of great practical interest. L. M. Milne-Thomson, USA

3796. Paterson, J. H., Recent developments in the hydrodynamic design of flying boats, *J. roy. aero. Soc.* **59**, 533, 349–355, May 1955.

3797. Miyamoto, H., Hydrodynamic resistance of a plane net, *Inter. Shipbldg. Progr.* **2**, 11, 291–318, 1955.

3798. Keller, J. B., and Kolodner, I., Instability of liquid surfaces and the formation of drops, *J. appl. Phys.* **25**, 918–921, 1954.

The theory of Taylor instability [G. I. Taylor, *Proc. roy. Soc. Lond.* (*A*) **201**, 192–196, 1950; see AMR **4**, Rev. 757; R. Bellman and R. H. Pennington, *Quart. appl. Math.* **12**, 151–162, 1954] is extended to the case of a liquid layer of thickness h between two parallel free boundaries (e.g., of gas) at different pressures, p_1, p_2. The most unstable perturbation mode is then calculated, with surface tension T included, and used to predict a mean drop radius r under breakup. The final formula is $r = [9\pi T h^2/2|p_2 - p_1|]^{1/3}$; no comparisons with experimental data are given. G. Birkhoff, USA

3799. Allen, J., and Albinson, B., An investigation of the manifold problem for incompressible fluids with special reference to the use of manifolds for canal locks, *Proc. Instn. civ. Engrs.* **4**, 1, part 3, 114–138, Apr. 1955.

Problem of equal discharge from manifold ports into canal locks led to the calculation of port area and a check by experiment. Calculations were based on energy equation including K losses at manifold entrance and port entrances, and friction losses between ports. Coefficients were assumed constant throughout. Tests using 2-in. pipe and adjustable ports gave good agreement with theory. Paper includes tables of results and curves for various ratios of port and manifold areas as well as considerable data to justify use of constant K values. Last port showed considerable variation, and suggestion is made that last 10% of ports be made 5% larger than required by theory. D. G. Huber, Canada

3800. Kravtchenko, J., Sauvage De Saint-Marc, G., and Boreli, M., Singularities of plane and permanent gravity flow of ground water (in French), *Houille blanche* **10**, 1, 47–62, Jan./Feb. 1955.

Paper provides a valuable introduction to the problems of free surface flow of ground water by the method of singularities. This method has been developed mainly in the USSR for problems of percolation through earth dams and into drains. Authors have done a great service to engineers by drawing their attention to the power and generality of these methods, which are little known outside Russian publications.

In their derivation of the theory, authors use a simplification of the method of Polubarinova-Kochina which they claim to be more rapid and direct. The results obtained constitute an extension of her theory which is of interest to the engineer.

It is unfortunate that no diagrams accompany the theoretical discussion. These would have helped readers not conversant with this branch of analysis to follow the complex and hodograph transformations and would have placed the study of the particular cases in a form in which the designer could immediately appreciate their value. A. Gordon Foster, England

3801. Gumbel, E. J., The calculated risk in flood control, *Appl. sci. Res.* (*A*) **5**, 4, 273–280, 1955.

A statistical function, the return period, will be linked to the calculated risk in order to obtain the value of the variable to be used in the design of a structure. From author's summary

Incompressible Flow: Laminar; Viscous

(See also Revs. 3794, 3798, 3840, 3845, 3846, 3850, 3861, 3869, 3886, 3888, 3900, 3910, 3918, 3939, 3940, 3942, 3950, 3953, 3959)

3802. Lüst, R., and Schlüter, A., A special kind of solution of the hydrodynamic equations with nonzero velocity curl (in German), *ZAMM* **35**, 1/2, 45–47, Jan./Feb. 1955.

The problem of inviscid and incompressible flow fields for which the streamlines are parallel to the vortex lines is considered. General equations for axisymmetric fields are derived. Solution is given for the case in which the velocity is a function of the distance from the origin only. The flow field consists of spherical shells within which the streamlines are closed. A special case is the vortex motion inside a sphere moving at constant velocity through a fluid at rest. W. L. Haberman, USA

3803. Hasse, D., Flow in a 90° elbow (in German), *Ing.-Arch.* **22**, 4, 282–292, 1954.

The investigations show that under certain assumptions it is possible to describe the complicated flow phenomena in an elbow (at least in the vicinity of the turning) by a potential flow; that is to say, if the velocity is nearly constant over the cross section before turning (e.g., due to short inflow distance when the boundary layer is thin) so that secondary flows can be avoided. In particular, there exists a thin transition region between the "dead water" region and the healthy flow, in spite of the strong motion in the dead water region, which transition region may be considered as a surface of discontinuity. The separation point ahead of the external knee point may be determined by the Gruschwitz method and its position agrees fairly well with experimental results, in spite of the strong assumptions made. It seems that the influence of the corner eddy is limited to a small region around the knee point (outside corner).

From author's summary by T. P. Torda, USA

3804. Rahnberg, G., On the rectilinear vortex filament in a cylinder, *Appl. sci. Res.* (*A*) **5**, 1, 12–30, 1954.

Vortical induced motion bounded by stagnated fluid and/or rigid boundaries is studied for the inviscid, incompressible, irrotational case. Basic assumption is that all motion is at speed in excess of a critical constant characterizing the fluid. Problem is considered in the hodograph plane and suitable conformally mapped regions. Results indicate conditions under which flow is steady or symmetric when filament is adjacent to single, parallel, and intersecting plane boundaries. Classical results are deduced as special cases. J. R. Baron, USA

3805. Skavlem, S., and Tjotta, S., Steady rotational flow of an incompressible, viscous fluid enclosed between two coaxial cylinders, *J. acoust. Soc. Amer.* **27**, 26–33, 1955.

By successive approximations at low Reynolds number, author calculates the unsteady viscous flow between coaxial cylinders of which the inner one oscillates harmonically in a plane. To the second approximation, the results show that there exist

two stationary circulatory systems in every quadrant and that the direction of circulation is opposite in these systems. The numerical results compare favorably with experiments.

Y. H. Kuo, USA

3806. Yamada, H., On the slow motion of viscous liquid past a circular cylinder, *Rep. Res. Inst. appl. Mech. Kyushu Univ.* **3**, 9, 11–23, Apr. 1954.

Using Oseen's linearized equations, an estimate is made of the Reynolds number at which rear twin-vortexes should appear. Value of 3.02 agrees satisfactorily with experimental value of 2.65 due to H. Nisi and A. W. Porter ["On eddies in air," *Phil. Mag.* (6), **46**, 754–768, 1923].

From consideration of pressure distribution round a cylinder derived by two methods, author concludes that Oseen's approximation is inadequate for the study of flow near the cylinder at greater values of Reynolds number.

G. D. S. MacLellan, England

3807. Lessen, M., Note on the propagation of infinitesimal disturbances in gases according to the Navier-Stokes equations, *J. aero. Sci.* **21**, 849–850, 1954.

The author derives the linearized partial differential equation satisfied by an arbitrary density disturbance in perfect gas with linear viscosity and heat conduction. This is an equation of fifth order. He remarks that shear modes propagate independently of longitudinal disturbances. (The author's attributions are misleading. He does not "generalize to any stress disturbance" the analysis of the reviewer [*J. rat. Mech. Anal.* **2**, 643–741, 1953; AMR **7**, Rev. 1531] which concerned the solution of the characteristic equation. The author's remarks on the isothermal and isentropic limits are essentially the same as those of Lamb, which are repeated on p. 659 of the reviewer's paper.)

C. Truesdell, USA

3808. Pai, S. I., On a generalization of Synge's criterion for sufficient stability of plane parallel flows (Note), *Quart. appl. Math.* **12**, 2, 203–206, July 1954.

In a previous paper [Semi-centennial Publ., Amer. math. Soc., vol. 2, 227–269, 1938] Synge derived sufficient conditions for the stability of plane Couette flow and plane Poiseuille flow of incompressible fluid. In the present note, the conditions are generalized so that the problem of velocity profiles with point of inflection and with either finite or infinite boundary condition or both may be included.

From author's summary

3809. Wuest, W., Flow through slits and holes with small Reynolds number (in German), *Ing.-Arch.* **22**, 357–367, 1954.

By Stokes' approximation, viscous flows through a slit and a hole are calculated by introducing elliptic, spherical, and ellipsoidal coordinate systems. In the plane case, if the flow is radial, it is calculated for moderate Reynolds numbers as well by extending the range of the variable in the well-known divergent channel flows.

Y. H. Kuo, USA

3810. Yalin, S., Flow in porous heterogeneous media (in German), *Bull. tech. Univ. Istanbul* **7**, 7, 59–78, 1954.

Paper discusses flow in a horizontal heterogeneous stratum. Heterogeneity is supposed due to continuous spatial variation of the (isotropic) flow permeability, especially with depth. For linear variation of permeability with depth, the partial differential equation, $H_{xx} + H_{yy} + H_y/y = 0$, is developed; H is hydraulic-head energy-function, y is directed vertically upward, x is horizontal as is z, and z-dependences are supposed to be zero. This equation defines "quasi-potential flow." It is integrated, by means of exponential and cylinder functions, for flow under a certain dam of finite length but neglecting end effects. Integration is rather fully presented and results are also expressed numerically and graphically.

From author's summary by F. T. Rogers, Jr., USA

3811. Hartley, D. E., Theoretical load distributions on wings with cylindrical bodies at the tips, *Aero. Res. Counc. Lond. curr. Pap.* 147, 39 pp., June 1952, published 1954.

The effect of tip tanks on spanwise lift distributions is investigated theoretically for the case of minimum induced drag in incompressible potential flow.

Charts enabling rapid estimation of the changes in span loadings, total lifts, and induced drags are presented for a practical range of the ratio of tank diameter to wing span.

It is shown how the results may be applied approximately to wings of any planform, including those with sweep or of low aspect ratio.

From author's summary

3812. Brebner, G. G., The application of camber and twist to swept wings in incompressible flow, *Aero. Res. Counc. Lond. curr. Pap.* no. 171, 59 pp., Mar. 1952, published 1954.

A certain type of chordwise vorticity distribution, applicable to a thin wing of any sweep in incompressible flow, is combined with the general equation for the downwash induced at any spanwise position on a swept wing by the spanwise vortexes. By applying the "streamline condition" that there is no velocity component perpendicular to the wing surface, and integrating over the chord, the equation of a camber line is obtained. The initial vorticity distribution contains two parameters which are related to the amount of camber and the chordwise position of the maximum ordinate, and thus define a doubly infinite family of camber lines. Expressions are found for the effect of these camber lines on the zero lift angle, lift distribution, and center of pressure at all spanwise positions. Simple charts are provided from which may be read the equivalent incidence and pitching moment at zero lift of any camber line of the family at any spanwise position on a wing of any sweep.

From author's summary

3813. Redshaw, S. C., The use of an electrical potential analyser for the calculation of the pressures on lifting surfaces, *Aero. Quart.* **5**, part 3, 163–175, Sept. 1954.

Author investigates the pressure distribution over lifting surfaces in a uniform subsonic flow by means of an electrical potential analyzer consisting of a cubic mesh of resistors. Paper contains a derivation of the theoretical analogy between the electrical potential and the velocity potential of the flow over an airfoil and gives experimental results for the following lifting surfaces: (a) rectangular wing (constant chord, aspect ratio 6); (b) delta wing (45° sweep, aspect ratio 4); (c) sweptback wing (45° sweep, aspect ratio 3).

The pressure distributions are shown in very instructive perspective pictures. Results are in good agreement with calculations based on the vortex theory. Paper proves that the electrical potential analyzer is an easily handled instrument compared with the electrolytic tank.

K. Pohlhausen, USA

3814. Knapp, W. C., and Metzger, J. W., Graphical representation of the frictional losses in commercial pipe of air and steam flowing turbulently at low pressure, *Trans. ASME* **77**, 5, 675–681, July 1955.

See AMR **8**, Rev. 1716.

3815. Bohnet, W. J., and Stinson, L. S., Fanning friction factors for air flow at low absolute pressures in cylindrical pipes, *Trans. ASME* **77,** 5, 683–692, July 1955.

See AMR **8,** Rev. 2037.

3816. Kurihara, M., Note on the hydrodynamical roughness length of a grass-field, *Proc. 1st Japan nat. Congr. appl. Mech.,* 1951; Nat. Committee for Theor. appl. Mech., May 1952, 481–484.

Compressible Flow, Gas Dynamics

(See also Revs. 3670, 3841, 3842, 3844, 3847, 3855, 3884, 3911, 3914)

3817. Castoldi, L., Bernoulli's theorem for a viscous compressible fluid (in Italian), *Atti Accad. Ligure* **9** (1952), 215–221, 1953.

The author seeks to generalize the theorem of Bernoullian type obtained by the reviewer [AMR **4,** Rev. 796]. His line of argument has meanwhile been put in yet more general form by the reviewer [chap. VII, especially §74, of "The kinematics of vorticity," Indiana Univ. Press, Bloomington, 1954, see AMR **7,** Rev. 3936]. The author considers special cases when the result is particularly simple. He points out that through each point there pass, in general, infinitely many curves on which the classical Bernoullian expression is constant. If the viscosity approaches zero, any one of these curves will approach a curve on Lamb's surfaces in classical hydrodynamics.

The author takes issue with the reviewer on two points. One of these is a matter of taste or as yet undevised experiment: the author regards the mean pressure, in any homogeneous viscous fluid, as an assignable function of density only, while the reviewer is not aware of any reason or evidence in favor of this opinion. The second relates to the special choice of Bernoullian lines made by the reviewer. This special choice determines the Bernoullian lines from the instantaneous velocity field alone, and the reviewer's objective was to show that such lines exist and to find them. This advantage is not preserved in the author's treatment, which, in effect, defines Bernoullian lines as any curves on the surfaces where the classical Bernoullian expression is constant. C. Truesdell, USA

3818. Lighthill, M. J., Mathematical methods in compressible flow theory, *Comm. pure appl. Math.* **7,** 1, 1–10, Feb. 1954.

3819. Bergman, S., Tables for the determination of fundamental solutions of equations in the theory of compressible fluids, *Math. Tables Aids Compt.* **9,** 49, 8–14, Jan. 1955.

In previous papers, author has shown that, in application of hodograph method for solutions of title problem, it is useful to consider stream and potential function in pseudologarithmic plane. To facilitate construction of singular type solutions, tables of certain quantities for complex values of arguments are presented. Y. L. Luke, USA

3820. Asaka, S., Application of the thin-wing-expansion method to the flow of a compressible fluid past a symmetrical circular arc aerofoil, *J. phys. Soc. Japan* **10,** 6, 482–492, June 1955.

Imai's method for calculating the flow round thin wings is presented in a somewhat modified and extended form and is applied to the case of symmetrical arc airfoils. Analytical expressions for the velocity potential and the velocity distribution are given. The accuracy of the method and its rate of convergence are discussed. For $M \leqslant 0.7$ and a thickness ratio t of about 0.1 or less, the iteration process used appears to be satisfactory. However, some comparisons made between measured and calculated velocity distributions for $M = 0.8$ and $t = 0.12$ show poor agreement. Author suggests this is due to boundary-layer effects and the possible appearance of weak shock waves.

W. P. Jones, England

3821. Oswatitsch, K., and Keune, F., Equivalence theorem for wings with zero angle of attack, small aspect ratio, and at M around 1 (in German), *Z. Flugwiss.* **3,** 2, 29–46, Feb. 1955.

It is the purpose of this paper to offer a proof of the validity of the following statements: The solution for transonic flow around a wing of small span and around a slender body of revolution can be divided into two parts. The first, called the "cross-section flow," satisfies the two-dimensional Laplace equation in planes normal to the free-stream direction and fulfills the boundary conditions on the body. The second, called the "spatial influence," is rotationally symmetric, depends on only the longitudinal distribution of cross-section area and the Mach number, and is constant over the cross section in the vicinity of the body. The wing and body of revolution are said to be "equivalent" if the longitudinal distributions of cross-section area are identical. The equivalence theorem states that "the spatial influence for a wing of small span is equal to that for an equivalent body of revolution."

This very interesting rule was first suggested by Oswatitsch at the Eighth International Congress for Theoretical and Applied Mechanics at Istanbul in 1952, and has previously been proved correct within the confines of the linearized theory of compressible flow. The present paper is concerned with a new derivation to extend the theorem to nonlinear transonic flow.

There is little doubt that this rule will have a major effect on the understanding of transonic flow and on the development of the theory. There remain questions of detail in connection with the proof, however. The demonstration hinges on a long and complicated evaluation of orders of magnitude following what, in essence, is the first step of an iteration procedure. In view of the fact that nearly every other existing iteration scheme fails in the transonic range, it would appear that the validity of the present procedure should be established by the author. A further criticism is that the analysis is based on the equations for shock-free flow. J. R. Spreiter, USA

3822. Von Baranoff, A., Resistance of a tapered body of rotation in accelerated or decelerated movement (in French), *C. R. Acad. Sci. Paris* **240,** 591–593, 1955.

The reviewer's published results on transonic drag [*J. aero. Sci.* **21,** 644–645 1954, see AMR **8,** Rev. 1427] are extended over a wider range of Mach number. The algebraic results are in agreement with unpublished results of the reviewer and L. Wong, but the numerical results are not. In particular, the author obtains numerical values of the transonic drag in excess of the limiting, supersonic value, whereas the reviewer's results (loc. cit. ante) prove this to be impossible. J. W. Miles, USA

3823. Kryučin, A. F., On the problem of transonic flow about a profile (in Russian), *Prikl. Mat. Mekh.* **18,** 547–560, 1954.

To approximate the symmetrical flow at Mach number M_∞ parallel to the x-axis with detached shock about a rhombus of small thickness τ, introduce dimensionless coordinates and velocities by $u/a^* = 1 - \epsilon U/(\kappa + 1)$, $v/a^* = \epsilon^{1.5}V/(\kappa + 1)$, $X = x/l^*$, $Y = \epsilon^{0.5}y/l^*$, where l^* denotes some reference length, a^* critical velocity of sound, κ adiabatic exponent, and $\epsilon^{1.5} = (\kappa + 1)\tau$. To terms of order ϵ^3 the equations of steady inviscid plane flow with vorticity imply

$$U\partial^2 Y/\partial V^2 + \partial^2 Y/\partial U^2 = 0 \qquad [1]$$

In the UV-plane impose on Y well-known boundary conditions correct to the lowest-order terms in ϵ on the approximate shock polar and on the three images of the line of symmetry, a front face of the rhombus, and the upper corner of the rhombus. Starting from a Fourier series (in V) solution of [1] obtained by separation of variables, author develops a method suitable for numerical computation of an approximate solution of this boundary-value problem. Approximate parametric equations are found for shock and sonic line, and the ratio of shock separation to the length of a front face of the rhombus has been computed as a function of the transonic similarity parameter $\Lambda = 2(1 - M_\infty)/\epsilon$.

J. H. Giese, USA

3824. Dewey, P. E., A preliminary investigation of aerodynamic characteristics of small inclined air outlets at transonic Mach numbers, *NACA TN* 3442, 21 pp., May 1955.

The aerodynamic characteristics of several outlets with inclined or curved axes discharging air into a transonic stream have been investigated. The data presented show the discharge coefficient of such outlets and the static-pressure distribution in the vicinity of the outlets for several values of stream Mach number and discharge flow parameter. Tuft observations, showing the vortex formation caused by the outlet discharge from a perpendicular and an inclined outlet, are also presented.

From author's summary

3825. Kusukawa, K., On the supersonic flow of elastic medium past a cone, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 15–18.

Paper is one of a series; it discusses flow patterns which are not irrotational and shows that the intensity of the shock decreases when the coefficient of friction increases. For a suitable value of the coefficient of friction, irrotational flow can take place on the surface of the cone.

W. Freiberger, USA

3826. Donaldson, I. S., The effect of sting supports on the base pressure of a blunt-based body in a supersonic stream, *Aero. Quart.* **6**, part 3, 221–229, Aug. 1955.

Experiments have been made to find the effect of the ratio of sting to base diameter on the base pressure of an axially symmetric body at zero incidence in a supersonic stream. The Mach number of the flow was 1.994 and the model boundary layer was turbulent. The model used was a 1-in. diam circular cylinder without boat-tailing. It passed through and was supported upstream of the nozzle throat. This method of support allowed measurements to be made in the important (and hitherto unexplored) case of zero sting diameter.

As the sting-to-base-diameter ratio was increased from 0 to 0.85, the base pressure decreased. The minimum value reached was approximately 0.8 of the value it would have at the base of a two-dimensional body with similar ratio of boundary-layer thickness to base height. The base pressure coefficient rose rapidly to zero as the ratio was further increased to unity.

Under the conditions of the experiments, with a sting-to-base-diameter ratio of 0.4, the base pressure coefficient differed from that without a sting by approximately 10%. With the more modest ratio of 0.2, the difference was approximately 3%.

From author's summary

3827. Ehlers, F. E., The lift and moment on a ring concentric to a cylindrical body in supersonic flow, *J. aero. Sci.* **22**, 4, 239–248, Apr. 1955.

Author calculates the supersonic flow at an angle of attack about a ring concentric to an infinite circular cylinder. The analysis is based on the linearized flow equations and the use of Laplace transforms. Pressure distributions on the ring and body as well as formulas for lift and moment are given.

In reviewer's opinion, much of the analysis is invalidated due to inadequate solutions pertaining to the flow between the ring and cylinder. This results from an inattention to the way incoming and outgoing waves appear in the interior problem. As given, the pressure due to thickness on the inside surface of the ring is merely the rough approximation provided by the assumption of unidimensional flow and fails to show the necessary explicit dependence on surface slope. Here, and elsewhere, the physical nature of the problem is misinterpreted.

M. A. Heaslet, USA

3828. Aslanov, S. K., Weakly supersonic flow of an ideal gas about a thin wedge (in Russian), *Prikl. Mat. Mekh.* **18**, 561–572, 1954.

Under the usual transonic approximations the shock in flow at Mach number M_1 with adiabatic exponent κ about a finite wedge of half angle δ becomes attached when the similarity parameter

$$K_1 = (M_1^2 - 1)/[(\kappa + 1)\delta]^{2/3} = K_* = 3/2^{4/3}$$

and for $K_1 = K_{1\mathrm{im}} = 2^{1/3}$ the shock becomes straight. For $K_1 > K_{1\mathrm{im}}$, the wave-drag coefficient is approximated by (1) $C_x = 4(K_1 - K)\delta^{5/3}/3(\kappa + 1)^{1/3}$, where $K(K_1)$ is the middle root of $(K_1 - K)^2(K_1 + K) = 2$. For $K_1 < K_{1\mathrm{im}}$ the author approximates the shock by a parabola $x = ay^2 - x_a$, the sonic line by either $x = 1$ or $x = 1 - y\delta/C$, where shock vertex curvature $2a$, shock separation x_a, and C are constants to be determined. Now (2) $C_x = C_x^0\delta^{5/3}(\kappa + 1)^{-1/3} + C_x^*$, where C_x^0 is J. D. Cole's [AMR **4**, Rev. 4527] value at Mach 1, $C_x^* = 2\int(\Delta S/\kappa R M_1^2)dy$, R is the gas constant, and ΔS the change in specific entropy at the shock. The integrand of C_x^* is crudely estimated and the integration is carried only to the sonic point of the shock to obtain $C_x^* = (A_1K_1 - A_2K_1^2)\delta^{5/3}(\kappa + 1)^{-1/3}$, where A_1 and A_2 are known functions of x_a, a, C, δ, M_1, and other undisturbed stream parameters. By requiring dC_x/dK_1 to assume the value given by Cole at Mach 1, $x_a = 0$ at $K_1 = K_*$, and equality of (1) and (2) at $K_1 = K_{1\mathrm{im}}$ the author obtains three relations involving A_1 and A_2 from which x_a, a, and C can be found as functions of M_1, δ, etc. The resulting C_x agrees well with H. W. Liepman's and A. E. Bryson's [*J. aero. Sci.* **17**, 745–755, 1950] test data for $K_1 < K_{1\mathrm{im}}$. To improve agreement for $K_1 > K_{1\mathrm{im}}$, the author recomputes and approximates $C_x = (A_1K_1^{-1/3} - A_2K_1^{-2})\delta^{5/3}(\kappa + 1)^{-1/3}$ by using similar approximations to $\int(\Delta S/R)dy$.

J. H. Giese, USA

3829. Kališevič, I. Z., Approximate integration of the equation of plane vortical supersonic motion of a gas (in Russian), *Dokladĭ Akad. Nauk SSSR* (*N.S.*) **99**, 37–40, 1954.

Let $\psi(\sigma, \theta)$ be the stream function for a steady flow, $\sigma = p/\rho_0 V_0^2$ dimensionless pressure, θ the inclination of the velocity to the x-axis, $\lambda = V/a_*$ dimensionless speed of flow, and a_* critical speed of sound. Then

$$\lambda\psi_{\sigma\sigma} - \lambda_{\sigma\sigma}\psi_{\theta\theta} - 2\lambda_\sigma\psi_\sigma - \lambda_\psi(\psi_\sigma)^2 - \lambda_{\sigma\sigma\psi}(\psi_\theta)^2 = 0 \qquad [1]$$

where subscripts denote partial differentiation, and λ can be found explicitly from Bernoulli's equation as a function of σ and $\vartheta(\psi) = p/\rho^k$ for adiabatic exponent k. However, to compel [1] to have fixed characteristics, author uses a four-parameter family of approximations

$$\lambda = w_1(\sigma) + w_2(\sigma)\mathfrak{J}_*(\psi)$$

where $w_{1\sigma\sigma}/w_1 = w_{2\sigma\sigma}/w_2 = m^2 = \text{constant}$, and $\mathfrak{J}_*(\psi)$ is at present arbitrary. Then [1] reduces to a type of equation solved

by S. V. Vallander in a form depending in the present case on a solution of [2] $v_{\sigma\sigma} - m^2 v_{\theta\theta} + 2m$ cth $(m\sigma + a)v_\sigma = 0$ for constant a. When cth $(m\sigma + a)$ is approximated by $1/(m\sigma + a)$, [2] reduces to an Euler-Darboux equation, and Vallander's solution yields an approximation to ψ in terms of three arbitrary functions and four parameters. The map from the (σ, θ)-plane to the (x, y)-plane is given by quadratures.

J. H. Giese, USA

3830. Voellmy, H. R., Aerodynamic forces on slender bodies of revolution (in German), *ZAMP* **5,** 3, 263–269, 1954.

Measurements of the normal force on slender bodies of revolution with varying base areas in supersonic flow are compared with Munk's slender-body theory and linearized potential flow theory. Wide discrepancies due to viscous effects are noted. For large angles of attack and slightly boattailed bodies, H. J. Allen's inclusion of a viscous cross-flow term is found to yield satisfactory reslts. A more sophisticated semi-empirical approach is given by H. R. Kelly [*J. aero. Sci.* **21,** 8, 549–555, Aug. 1954]. For small angles of attack and strongly boattailed bodies, improved agreement is attained by a reinterpretation of the slender-body theory. The normal force is determined not by integration over the entire body but only up to the station of minimum pressure; hence the effective base area is increased.

H. A. Linstone, USA

3831. Clippiner, R. F., Supersonic axially symmetric nozzles, *BRL Aberdeen Prov. Gr., Md., Rep.* no. 794, 38 pp., 1951.

Calculations of isentropic steady flow in round nozzles have been carried out by the method of characteristics on the ENIAC machine. The theory is derived here and the approximation by difference equations is explained in detail. Results are given for twenty nozzles: four at each of five exit Mach numbers. Results are available at the Ballistic Research Laboratories for ten nozzles, of various lengths, at each of 21 exit Mach numbers ranging from 1.008 to 8.238. The tables given here are samples. The nozzles are designed for a plane sonic surface at inlet and for uniform outlet conditions.

W. R. Sears, USA

3832. D'yakov, S. P., Shock waves in binary mixtures (in Russian), *Zh. tekh. Fiz.* **27,** 283–287, 1954.

For one-dimensional steady flow, author formulates equations for conservation of mass (for the mixture and for one component), of momentum, and of energy, taking into account viscosity, heat conduction, diffusion, thermal diffusion, and pressure diffusion. He expands the changes of enthalpy and specific volume to terms of second order in the change of pressure p and to first order in the changes of entropy and of the concentration c of one component to obtain an ordinary differential equation that can be solved explicitly for $p(x)$. This yields an estimate of the thickness of the shock and also implies that $c(x)$ rises from its value c_0 ahead of the shock to a maximum and then returns to c_0. Also considered is a suspension of dust particles for which it is found that the shock width is increased, and the concentration of dust particles decreases in the shock.

J. H. Giese, USA

3833. D'yakov, S. P., Shock waves in relaxing media (in Russian), *Zh. eksp. teor. Fiz.* **27,** 5(11), 728–734, Nov. 1954.

In the transition zone of a shock wave, the thermodynamic state is out of equilibrium and therefore tends to regain it by internal processes (relaxation). The existence of several types of shock waves in relaxing media is discussed, one of which is accompanied by falling pressure. In the case of weak shocks it is assumed that the deviation from equilibrium is small and that the velocity of change is proportional to the deviation itself. A formula for the thickness of the transition zone and the pressure fall is derived.

W. Wuest, Germany

3834. D'yakov, S. P., Stability of shock waves (in Russian), *Zh. eksp. teor. Fiz.* **27,** 3(9), 288–295, Sept. 1954.

Author finds the general solution for spherical motion of adiabatic gases with a rather general initial mass and pressure distribution in a gravitational field; the integrals are simple when $\gamma = 4/3$; particular solutions illustrated are outgoing blast waves, ingoing spherically focusing waves, and pulsations of a sphere of gas in vacuum.

L. Trilling, USA

3835. Broer, L. J. F., On the theory of shock structure—III, *Appl. sci. Res.* (*A*) **5,** 1, 76–80, 1954.

For two ideal gases with constant properties, one having shear and bulk viscosity but no relaxation, the other having only shear viscosity and relaxation, author calculates the velocity profiles of a normal shock wave using his previously developed theory [I, AMR **6,** Rev. 2295; II, AMR **7,** Rev. 2906). For the first gas, the Prandtl number becomes $3/4\ (1 + b)$, where $b = 3\lambda/4\nu$ is the bulk viscosity number. The effect of bulk viscosity is to broaden the profile. Similarly, there is a broadening effect on the profile in the second gas, but it is larger by the factor n, where n is the number of molecular collisions to establish equilibrium. A table of values of shock-wave shapes shows that n must be >10 before the effects of relaxation become more significant than those of bulk viscosity.

R. E. Street, USA

3836. Roy, M., Formulas for shock waves in steady two-dimensional flow (in French), *C. R. Acad. Sci. Paris* **238,** 2369–2372, 1954.

Author derives explicit expressions for the values and/or gradients along the shock of various state variables immediately behind a curved two-dimensional stationary shock. The flow in front of the shock is an isentropic and isoenergetic flow of an ideal fluid and the quantities are obtained in terms of the state variables and their derivatives in front of the shock. In particular, a relatively simple expression has been obtained for the vorticity immediately behind the shock. Some deductions are made from the derived formulas, especially for various special cases; but it should be noted that similar formulas and deductions have been or could be obtained from previous papers on this topic, as, for example, C. C. Lin and S. I. Rubinov, *J. Math. Phys.* **27,** 105–129 1948 [AMR 1, Rev. 1391].

P. Chiarulli, USA

3837. Murasaki, T., On propagation of strong shock waves through a duct of variable cross section (in Japanese), *Rep. Inst. Sci. Technol. Tokyo* **8,** 5, 197–204, Oct. 1954.

3838. Holder, D. W., Pearcey, H. H., and Gadd, G. E., The interaction between shock waves and boundary layers, *Aero. Res. Counc. Lond. curr. Pap.* no. 180, 50 pp., 49 figs., Feb. 1954, published 1955.

Paper was written as a guide to literature on subject title, and presents detailed descriptions of physical processes involved for various flow regimes together with underlying reasons for observed behavior. The mathematics is held to a minimum, but text is amply augmented with experimental plots and excellent photographs. Paper is divided into four parts with subject headings as follows: Part I, Experiments designed to provide fundamental information on the interaction; Part II, The effects of the interaction on airfoils and wings; Part III, The effects of the interaction on the performance of supersonic intakes; Part IV, Notes on further work which is required.

Part I discusses the interaction between the boundary layer on a flat plate and on oblique shock generated externally by a wedge in the main stream. The interaction is found to depend primarily on the boundary-layer Reynolds number, free-stream Mach number, and the strength of shock, the greater effect occurring for laminar boundary layers. Conditions having serious practical effects downstream of interaction zone depend upon the degree of shock-induced separation.

Part II describes the effects of shock-induced turbulent boundary separation on a number of two-dimensional airfoils. The primary effects are found to be those on the circulation and relative shock positions on the upper and lower airfoil surfaces. Curves are presented illustrating the variation in lift coefficient and 1/4-chord pitching moment coefficient as a function of M_0 when separation occurs. Certain unsteady-flow phenomena such as buffeting and control surface "buzz" are discussed in relation to separation effects.

In part III a short discussion is devoted to the effects of the interaction of a pre-entry shock system and an external boundary layer in the vicinity of the entrance to a supersonic side intake. The various losses which go to determine the final pressure recovery at the engine result from friction in the external boundary layer ahead of the shocks, friction along the duct walls, shock losses, and a loss due to turbulent mixing in the zone following the shock-induced boundary-layer separation zone.

Part IV concludes with a list of suggestions for further work, and a plea for more experimental data on various aspects of the problem.

Reviewer heartily commends this excellent paper for its clear exposition and thorough coverage. C. E. Carver, Jr., USA

Turbulence, Boundary Layer, etc.

(See also Revs. 3838, 3886, 3907, 3908, 3909, 3923, 3953)

3839. Nichols, M. R., and Pierpont, P. K., Preliminary investigation of a submerged air scoop utilizing boundary-layer suction to obtain increased pressure recovery, *NACA TN* 3437, 72 pp., Apr. 1955.

Report presents low-speed engineering wind-tunnel tests of a fuselage scoop with a submerged air inlet for use on a high-speed fighter aircraft. Study includes effect of boundary-layer control, suction-slot location, model configuration, and variations of boundary-layer thickness on inlet performance. All results obtained are only applicable to subcritical flight Mach numbers. It was found that application of boundary-layer suction gave much better pressure recovery performance for relatively thin turbulent boundary layers ahead of the inlet. However, performance of the inlet dropped off rapidly with increase in thickness of the initial boundary layer, in spite of increased suction.

Reviewer feels the value of this report is somewhat limited, since no indication is afforded of the change in pressure recovery characteristics due to boundary-layer shock-wave interaction, because of the restriction to low speeds.

R. F. Probstien, USA

3840. Stuart, J. T., On the effects of uniform suction on the steady flow due to a rotating disk, *Quart. J. Mech. appl. Math.* **7**, part 4, 446–457, Dec. 1954.

The exact ordinary differential equations of von Kármán for the flow due to a rotating disk of infinite radius are integrated for the case of uniform suction through the disk. In the analysis a suction parameter a is introduced, where $a(\gamma\omega)^{1/2}$ is the velocity of suction, γ being the kinematic viscosity and ω the angular velocity of the disk. For $a = 1$ the equations are integrated numerically, but for higher values of a, a series solution in descending powers of a is obtained.

The magnitude of the radial component of flow is found to decrease rapidly as the suction increases, while at the disk the derivative of the tangential component—with respect to distance from the disk—increases. If the ratio of distance from disk to displacement thickness is used as the dimensionless independent variable, the change of the radial component with suction is seen to occur mainly in the velocity scale, with little change of shape, while the tangential component of flow changes very little.

From author's summary by M. J. Goglia, USA

3841. Van Driest, E. R., and Boison, J. C., Boundary-layer stabilization by surface cooling in supersonic flow, *J. aero. Sci.* **22**, 1, p. 70, Jan. 1955.

Note in Readers' Forum.

3842. Libby, P. A., and Pallone, A., A method for analyzing the heat insulating properties of the laminar compressible boundary layer, *J. aero. Sci.* **21**, 12, 825–834, Dec. 1954.

A two-dimensional boundary-layer flow is investigated in which localized upstream cooling by convection or injection is utilized to reduce the wall temperature of a downstream adiabatic surface. This situation could arise, for example, in cooling optical windows of hypersonic wind tunnels, radomes, or other surfaces where appreciable direct heat removal is not possible. The von Kármán integral method is applied to both the momentum and energy equations to determine the wall temperature variation downstream from the cooled section. Velocity and stagnation enthalpy profiles are approximated by sixth-degree polynomials. This is necessary to satisfy the usual boundary conditions at the wall and edge of the boundary layer, and, in addition, continuity of mass, momentum, energy, and boundary-layer thickness at the discontinuity where upstream cooling is terminated. For the case of zero pressure gradient in the flow direction, a solution in closed form is obtained. Two numerical examples indicate that upstream injection provides an attractive cooling method.

For convenience in calculating the conditions at the beginning of the adiabatic section, the appendix provides an analysis of the laminar boundary layer with injection. R. Siegel, USA

3843. Squire, L. C., Boundary layer growth in three dimensions, *Phil. Mag.* (7) **45**, 1272–1283, 1954.

An analysis is made of the boundary layer in three-dimensional flow immediately following an impulsive start from rest in an incompressible fluid. The argument used by Goldstein and Rosenhead for the analogous plane problem [*Proc. Camb. phil. Soc.* **32**, 392–401, 1936] is easily extended to three-dimensional boundary-layer flow. The second and third approximations are carried out, at least as far as the derivatives at the body surface, which yield the skin friction. The results are applied to an ellipsoid of axis ratios 30:6:1, which resembles a wing in symmetrical flow. The object is to determine the locus in space and time of the phenomenon of separation; this is preceded by a discussion of the criterion for separation in three-dimensional flow. It is concluded from the present calculations that separation first appears at the rear stagnation point at the midsection. This separation point then moves forward and separation begins on neighboring streamlines at points not coincident with the rear stagnation points; meanwhile streamlines farther outboard remain unseparated. The separated area expands outward as time progresses, and at a certain time all streamlines over the ellipsoid encounter separation. The times at which these various events occur are determined. W. R. Sears, USA

3844. Bruniak, R., Back flow and thickening in the laminar boundary layer in compression waves (in German), *Öst. Ing.-Arch.* **8**, 2/3, 87–90, 1954.

Ackeret-Feldmann-Rott pointed out the fact that back flow might exist in some region within the laminar boundary layer. On the other hand, it has been experimentally observed that the boundary layer is thickened by a shock wave. The present paper aims to give some theoretical explanations of these phenomena.

The velocity inside the boundary layer varies from zero to supersonic, having the critical velocity between them. Therefore, the boundary layer can be divided into two parts: one is the inner region where the velocity varies from zero to the critical velocity; the other is the outer region where the velocity varies from the critical velocity to supersonic.

If we denote the critical velocity as C^*, the velocities before and after the shock wave as u_1 and u_2, respectively, the relation $u_1u_2 = C^{*2}$ will hold. From this relation, it becomes possible to estimate the velocity distribution in both regions of the boundary layer behind the shock wave. In the outer region, energy and entropy behind the shock wave are found to have a gradient in the direction perpendicular to the wall. Consequently, according to Crocco's vortex law, vorticity will exist behind the shock wave. This vorticity accelerates or decelerates the x-component of the flow velocity and causes the cross flow. The change in velocity distribution would result in occurrence of the back flow, and the cross flow might induce the thickening in boundary layer.

Reviewer supposes that, in spite of its simple treatment, the present paper is interesting because of its clear explanations of several phenomena. T. Okamoto, Japan

3845. Rohlik, H. E., Kofskey, M. G., Allen, H. W., and Herzig, H. Z., Secondary flows and boundary-layer accumulations in turbine nozzles, *NACA Rep.* 1168, 32 pp., 1954.

Supersedes articles reviewed in AMR **6**, Revs. 3179, 3533, and AMR **7**, Rev. 843.

3846. Kostyukov, A. A., Resistance of bodies in a fluid to motion near a vertical wall (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **99**, 349–352, 1954.

Author writes down the integral for the wave resistance of a submerged body moving at constant velocity parallel to a rigid wall in a heavy fluid of finite depth. He notes that the resistance (for a body with the same source distribution) is always less than twice that when the wall is absent. The case of submerged source and dipole is also treated, including the lateral force. Author is apparently unaware of Lunde's paper [*Trans. Soc. nav. Arch. mar. Engrs.* **59**, 25–76, 1951, see AMR **5**, Rev. 1458] which treats exhaustively many problems of this sort [see pp. 44–50, 57–59]. J. V. Wehausen, USA

3847. Lobb, R. K., Winkler, Eva M., and Persh, J., Experimental investigation of turbulent boundary layers in hypersonic flow, *J. aero. Sci.* **22**, 1, 1–9, 50, Jan. 1955.

Turbulent boundary-layer profiles on the walls of a plane diverging nozzle in the presence of a slightly falling free stream pressure were surveyed at $M = 5$, 6.8, and 7.7. Wall temperature was varied by a cooling system and local heat-transfer coefficients were determined. Aside from pitot and static pressures, total temperature profiles were measured, permitting direct calculation of velocity profiles, displacement, and momentum thickness. Reynolds number based on momentum thickness varied from 5000 to 13,000. Local skin-friction coefficients were determined directly from the velocity gradients at the wall and indirectly from the temperature distribution in the wall and the Reynolds analogy. These two methods agreed surprisingly well and results are in line with supersonic direct friction measurements by Coles and Chapman and Kester. Displacement thickness is appreciably reduced by wall cooling while the effect on skin friction is slight but noticeable. Velocity distribution is linear in the laminar sublayer. The sublayer increases greatly with Mach number and decreases slightly with wall cooling, as predicted by Donaldson. The outer turbulent portion of the profile does not follow the logarithmic law and the n in the power profile representation decreases from 7 to 5.5 with increasing M from 5 to 7.7.

Present carefully measured data will be exceedingly useful due to lack of theoretical understanding of compressible turbulent boundary layers at high Mach numbers. These results are among the first where total temperature was measured in supersonic shear layers and, reviewer believes, the first to penetrate supersonic laminar sublayers. Presentation is clear and unambiguous and all raw data can be inferred from plots for further theoretical work. P. P. Wegener, USA

3848. Emmons, H. W., Shear flow turbulence, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 1–12.

Starting with the momentum and energy equations for turbulent shear flows, a system of equations is obtained for flows with a single dominant mean motion gradient ($d\bar{u}/dy$) by postulating on dimensional and physical grounds that the turbulent shear stress, energy diffusion, and energy dissipation terms are proportional to $E^{1/2}l\, d\bar{u}/dy$, div ($lE^{1/2}$ grad E) and $E^{3/2}l^{-1}$, respectively. E is the energy, and l the scale of the turbulence. This system of equations is applied to the cases of the decay of grid-generated turbulence, free turbulent flows, and channel and boundary-layer flows. The constants of proportionality as well as the magnitude of the scale are deduced in each case by comparison with experimental data. Values of the scale which are simply related to appropriate characteristic lengths for the flow problems considered give reasonable agreement with hot wire measurements. L. M. Grossman, USA

3849. Burgers, J. M., On turbulent fluid motion, *Hydrodyn. Lab. Calif. Inst. Technol., Pasadena, Calif. Rep.* no. E-34.1, 191 pp., July 1951.

Chapter headings are as follows: I Introduction; II Correlation functions; III The spectrum of a turbulent field; IV Some experimental data on the spectrum and on correlation; V Problems of turbulent spreading of particles, of heat and of momentum; VI Features of the Navier-Stokes equations; VII Application of a mathematical model to illustrate relation characteristic of turbulence; VIII Homogeneous isotropic turbulence.

This is not in the nature of an introductory textbook. It is a stimulating and detailed account of special aspects of the turbulence problem, largely the one-dimensional "model" (VII) and the semiquantitative, hueristic analyses (V, VI) devised by the author. Reviewer recommends it highly to experienced turbulence researchers and cautions neophytes that some of the simplifying postulates (especially in V and VI) would be difficult to justify a priori. S. Corrsin, USA

3850. Iwasaki, M., Yamauti, I., and Sugahara, A., Experiments of wakes behind cascades of accelerated flow, *J. Japan Soc. aero. Engng.* **3**, 13, 1–5, Jan. 1955.

Paper presents results of measurements on cascades with high stagger angle; it includes lift curve slopes and hot-wire measurements of velocity profiles and turbulence profiles in the wake. Measurements show that the wakes interfere only at extremely high stagger angles, in which case there is a large loss of lift.

A. Roshko, USA

3851. Spangenberg, W. G., Heat-loss characteristics of hot-wire anemometers at various densities in transonic and supersonic flow, *NACA TN* 3381, 82 pp., May 1955.

An experimental investigation was made of the heat-loss characteristics of heated fine wires suitable for use as anemometers in turbulence research. Speeds ranged from low subsonic to Mach number 1.9. Density and temperature loading were varied over wide limits, and wire diameters ranged from 0.00005 to 0.0015 in. The effects of each of the several variables on the heat-loss characteristics of both normally oriented and swept wires were measured. From author's summary

3852. Smith, A. M. O., and Murphy, J. S., A dust method for locating the separation point, *J. aero. Sci.* **22**, 4, 273–274, Apr. 1955.

Note in Readers' Forum.

Aerodynamics of Flight; Wind Forces

(See also Revs. 3622, 3651, 3726, 3727, 3728, 3729, 3780, 3811, 3812, 3813, 3820, 3823, 3826, 3830, 3850, 3863, 3864, 3865, 3867, 3879, 3887, 3914, 3952)

3853. Petroff, A. N., and Wattson, R. K., Jr., Take-off ground run of an airplane with forced circulation system of boundary-layer control, *Aero. Engng. Rev.* **14**, 6, 79–82, June 1955.

Ground run is calculated by simplified method of W. S. Diehl as a function of (1) ratio of power used for boundary-layer control to main engine power, (2) weight increase per horsepower used in boundary-layer control, (3) lift coefficient increment per horsepower used in boundary-layer control. Results indicate considerable decrease in take-off run with auxiliary power preferable to wing portion of main engine power.

A. E. Bryson, Jr., USA

3854. Kremzier, E. J., A method for evaluating the effects of drag and inlet pressure recovery on propulsion-system performance, *NACA TN* 3261, 21 pp., Aug. 1954.

An empirical graphical method of evaluating the ratio of aircraft thrust minus drag to ideal thrust, for any inlet pressure recovery in terms of flight conditions and conventional engine characteristics, is presented with working charts for airplanes with air-breathing propulsion system. Examples are included.

S.-I. Cheng, USA

3855. Legras, J., The second approximation of a wing in subsonic flow (in French), *Rech aéro.* no. 42, 17–21, 1954.

In the case of a slender wing, such as a delta wing, the integral equation for the circulation distribution $\Gamma(x, y)$ can be written

$$W_0(x, y) = -V\alpha(x, y) + W_1(x, y)$$

where V is the flight speed, $\alpha(x, y)$ is the local slope of the surface, and $W_0(x, y)$ is the upwash induced far downstream by the trailing vortexes. $W_1(x, y)$ denotes the remainder of the upwash at any point and is given by a surface integral involving the circulation distribution $\Gamma(x, y)$. The Munk-Jones approximation is $W_1 = 0$; i.e., the boundary condition is satisfied by the trailing vortexes. Here a second approximation is proposed in which the Munk-Jones results, say $\Gamma_0(x, y)$, are used to calculate W_1, at least after some numerical approximations to its kernel. For triangular wings, for example, an explicit result can then be obtained for W_1, but it is logarithmically infinite at the trailing edge. [This is presumably the same phenomenon encountered by Adams and Sears, *J. aero Sci.* **20**, 85–98, 1953, see AMR **6**, Rev. 3136.]

The author therefore applies Lighthill's technique (perturbation of independent variable) to remove this singularity in the second approximation. The effort is apparently successful. The equation for the coordinate shift is solved numerically. The resulting circulation distribution has the form

$$\Gamma(x,y) = K(x)(1 - \epsilon\Delta\alpha)\Gamma_0(x, y)$$

where $K(x)$ is a correction factor which removes the logarithmic singularity, and $\epsilon\Delta\alpha$ denotes regular second-order terms.

W. R. Sears, USA

3856. DeYoung, J., and Barling, W. H., Jr., Correction of additional span loadings computed by the Weissinger seven-point method for moderately tapered wings of high aspect ratio, *NACA TN* 3500, 31 pp., July 1955.

It has been found that, for wings combining high aspect ratio with large amounts of sweep, the Weissinger seven-point results are in error. A simple procedure is presented here which for a sizable range of planforms largely corrects these errors and results in more accurate span loadings being read directly from the loading charts of *NACA Rep.* 921. This procedure consists of an alteration of the taper ratio used plus an additional correction applied at the wing root. The lift-curve slope and the method of fairing the loading are also improved.

The new results agree within $\pm 1\%$ with theoretical results believed to be accurate; whereas maximum errors of the original Weissinger seven-point loading (for wings swept back 45°) are approximately 2 and 8% for aspect ratios equal to 3 and 10, respectively. From authors' summary

3857. Milwitzky, B., and Cook, F. E., Analysis of landing-gear behavior, *NACA Rep.* 1154, 45 pp., 1953.

Supersedes article reviewed in AMR **6**, Rev. 448.

3858. Serafini, J. S., Impingement of water droplets on wedges and double-wedge airfoils at supersonic speeds, *NACA Rep.* 1159, 24 pp., 1954.

Supersedes article reviewed in AMR **7**, Rev. 895.

3859. Martina, A. P., Method for calculating the rolling and yawing moments due to rolling for unswept wings with or without flaps of ailerons by use of nonlinear section lift data, *NACA Rep.* 1167, 16 pp., 1954.

Supersedes article reviewed in AMR **7**, Rev. 237.

3860. Donegan, J. J., Matrix methods for determining the longitudinal-stability derivatives of an airplane from transient flight data, *NACA Rep.* 1169, 20 pp., 1954.

Supersedes article reviewed in AMR **6**, Rev. 3163.

Aeroelasticity (Flutter, Divergence, etc.)

(See also Rev. 3644)

3861. Legendre, R., Elliptic functions and integrals with real modulus in fluid mechanics (in French), *ONERA Publ.* no. 71, 74 pp., 1954.

Author's aim has been to introduce to engineers a theory of Jacobian elliptic functions and related functions, and to indicate their application in fluid mechanics. Extensive use is made of the singularity method with a fluid mechanical interpretation, and proofs are given on an intuitive rather than rigorous basis. The more important functions are represented graphically by the streamlines and equipotential lines of the associated flow.

Some topics are: flow inside and outside a polygon, hodograph transforms, analytic continuation by reflection, definition of

Jacobian elliptic functions by elliptic integrals of first kind, addition theorems, transformations of Gauss and Landen, multiplication or division of the ratio of the periods by an integral number, development in trigonometric series, properties of the theta functions and their logarithmic derivatives, construction of elliptic function with given zeros and poles, elliptic integrals.

The following applications are presented briefly: (1) design of a cascade with laminar blades; (2) calculation of flow field around vibrating swallowtail wings, as an extension of author's previous work [AMR **7**, Rev. 3669]. H. G. Loos, USA

3862. Kilpatrick, D. A., and Ritchie, J., Compressor cascade flutter tests 20° camber blades, medium and high stagger cascades, *Aero. Res. Counc. Lond. curr. Pap.*, R.133, 10 pp., Dec. 1953, published as *curr. Pap.* 187, 1955.

Tests reported show the existence of three main zones of flutter at high stress; stalling flutter, shock-stalling flutter, and choking flutter. These zones are similarly located (with reference to the aerodynamic characteristics) for both the medium and the high stagger cascades tested, and they extend over a wide range of incidence. Good correlation between the zones of flutter and the experimentally measured blade force derivatives, with respect to Mach number and incidence, has been obtained. More experimental data are, however, required before a quantitative analysis of the problem can be achieved. From authors' summary

3863. Acum, W. E. A., Aerodynamic forces on rectangular wings oscillating in a supersonic air stream, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2763, 28 pp., Aug. 1950, published 1954.

Linearized theory is employed for the case of a rigid wing in simple harmonic motion. It is shown that, within the tip region, the solution for the potential can be reduced to the determination of a sum of solutions of the conical type, with steady flow a special case. The boundary condition on the wing surface is expanded in a power series chordwise, and the higher-order conical solutions are required to satisfy successive terms in the series.

The boundary condition on the cone surface is determined by evaluation, in series form, of the appropriate two-dimensional solution after expansion of the integrand Bessel function. The partial differential equations to be solved are then of the elliptic type with known boundary conditions; author employs "method of relaxation" to obtain numerical solution at discrete points. Completion of solution requires numerical integration of these results. Number of calculations to be accomplished depends on accuracy required, but author claims rapid convergence in cases considered.

Numerical results for lift and moment coefficients are presented for a range of Mach numbers from 1.2 to 2 and for three values of the flutter parameter. Author states that comparisons for special cases showed satisfactory agreement with the work of Temple and Jahn [*Rep. Mem.* 2140], Watkins [*NACA TN* 1895], and others.

In particular, effect of aspect ratio on damping in pitch is investigated. Author determines that aspect ratio has a stabilizing effect for axes less than approximately 0.7 chord, destabilizing for axes farther aft. The results show little variation with Mach number or frequency. H. M. Voss, USA

3864. Chopin, S., Approximation of aerodynamic forces at $M = 0.7$ **(in French),** *Rech. aéro.* no. 40, 21–26, July/Aug. 1954.

Author proposes to approximate, apparently by "fitting," the flutter aerodynamic coefficients of Dietze at $M = 0.7$ in such a way that the generalized aerodynamic forces may be represented by the same formula used by Kussner for $M = 0$. Reduction of computation time in flutter calculations is claimed.

S. F. Shen, USA

3865. De Jager, E. M., Tables of the aerodynamic aileron-coefficients for an oscillating wing-aileron system in a subsonic, compressible flow, *Nat. LuchtLab. Amsterdam Rap.* F.155, 21 pp., July 1954.

Report presents numerical results for the aerodynamic aileron coefficients of an oscillating wing-aileron system, where the aileron hinge axis coincides with the nose of the aileron. The complete set of the 5 complex coefficients is given for the Mach numbers 0, 0.35, 0.50, 0.60, 0.70, 0.80; the reduced frequency being equal to 0 (0.1) 1.0, and the chord ratio equal to 0 (0.02) 0.1 (0.05) 0.3. From author's summary

3866. Peacock, H. G. S., Flight flutter tests on the Gloster Javelin, *Aircr. Engng.* **27**, 313, 68–72, Mar. 1955.

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 3626, 3628, 3644, 3699, 3770, 3771, 3840, 3845, 3854, 3906, 3911, 3928, 3930, 3931)

3867. Driggs, I. H., and Lancaster, O. E., Gas turbines for aircraft, New York, The Ronald Press Co., 1955, xv + 349 pp. $10.

This introduction to aircraft gas turbines in eleven chapters treats: (1) Perspective; (2) Fundamentals; (3) Cycle analysis of gas turbines; (4) Flow of compressible fluids in tubes and passages; (5) Compressors; (6) Turbines; (7) Combustion; (8) Gas-turbine performance; (9) Control problems; (10) Aircraft performance analysis; (11) Early development of gas-turbine engines. It may be useful as a textbook for beginners in aeronautical and mechanical engineering, but may serve also as a reference book for engineers who are not experts in aerodynamics or turbomachinery, such as mechanical designers in engine groups, etc. The use of equations is frequently illustrated by numerical examples. Values of occurring physical quantities are represented by charts. Much use is made of graphical procedures for the solution of layout and design problems. In some cases, this may be of help also to the advanced engineer, if he is willing to use such predigested procedures. The plots of chronology of engine parameters and the historical sketch are of quite general interest. It would have been of more help if more references had been included. F. Weinig, USA

3868. Morgan, D. W. R., Jr., and Fulton, S. D., The economics of large reheat turbine-exhaust-end size selection, *Trans. ASME* **77**, 3, 363–371, Apr. 1955.

3869. Fraser, J. P., An approximate relationship between small radius ratio turbine passage geometry and radial pressure variation, *J. aero. Sci.* **22**, 4, 282–283, Apr. 1955.

Readers' Forum. The procedure, briefly summarized, was undertaken to give a first approximation to the deviation from a "vortex" radial pressure distribution in a nonvortex stage. To this end, incompressible and lossless flow are assumed. The relationships developed take into account passage geometry of nozzle and bucket at all axial stations. It is believed that this approach will assist in the approximate layout of nonvortex turbine stages having a radius ratio approaching unity.

From author's summary

3870. Barlow, E. L., Jr., The development of the first gas-turbine mechanical-drive locomotive, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-183, 11 pp.

3871. Fraser, W. H., Model tests on the 84-in. Tracy pumps, ASME Ann. Meet. N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-225, 9 pp.

3872. Cametti, B., Pumping in hermetically sealed systems, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-119, 12 pp.

3873. Korbacher, G. K., A unified notation for turbo machinery, *Univ. Toronto Inst. Aerophys. Rep. no.* **7,** 19 pp., Aug. 1954.

In gas-turbine analysis work, cascade tunnel investigations, and textbook treatment of turbomachinery, it would be very convenient and useful if a skeleton of identically applicable basic equations, common notations, and definitions, and a common convention of signs for angles, velocity vectors and forces, could be used for both centrifugal and axial-flow compressors and for turbines.

The purpose of this note is to present such a scheme. A skeleton of basic and identically applicable equations and coefficients is recorded and a system of common notation and a common convention of signs is defined. From author's summary

3874. Bensinger, W.-D., Control of aspiration in high-speed internal combustion engines [Die steuerung des gaswechsels in schnellaufenden verbrennungsmotoren], Berlin, Springer-Verlag, 1955, v + 93 pp. DM 12.

The first part of the booklet contains the statement of the problem together with a wide selection of constructive details on valve mechanism from German, English, and U.S. engines.

The following section is devoted to calculations for valves, springs, cams, and allied parts. Displacement, velocity, and acceleration diagrams for different cam forms are shown and the merits of each discussed; also torque diagrams of camshafts have been taken into consideration.

In the last part, sleeve valve I.C. engines are studied. The author, chief engineer with the famous Mercedes-Benz company, advocates sleeve valves for future development; e.g., "Aspin" or rotating disk construction.

All features are well discussed and accompanied by many illustrations and graphs. The numerous calculations of practical problems establish this booklet as an important aid for the design engineer, but, in order to benefit, the reader must be conversant with the metric system and also understand the rudiments of the German technical vocabulary. M. Rand, Canada

Flow and Flight Test Techniques

(See also Revs. 3624, 3791, 3850, 3852, 3871, 3921)

3875. Somervaille, I. J., The effective area of a piston gauge, *Austral. J. appl. Sci.* **6,** 2, 149–157, June 1955.

A numerical solution for the effective area formula is devised and explained. This procedure allows for diameter variations along the working length of each component. Such allowance is important for very high pressure measurements where small pistons in the order of 0.1 in. are used. The piston gage, primary gage for calibration of secondary standards, may be used instead of ordinary bourdon gage, thus eliminating need for frequent calibration. The present ASME standards permit greater variations than discussed in reviewed paper. Reviewer believes paper significant to manufacturers of precise high-pressure measuring devices, and engineers in the high-pressure field.

A. C. Tobey, USA

3876. Hübner, E., The measurement of small transient pressures (in German), *Forsch. Geb. Ing.-Wes.* **20,** 1, 20–31, 1954.

The most common devices for electric measurement of small membrane deflections (strain gages, mirrors with photoelectric cells, and inductance or capacitance boxes) are first described briefly. Membranes with the transmitting fluid and other parts of the apparatus form coupled oscillating systems; their electric analogies can be readily established and their mechanical behavior can be deduced, using the well-known methods of electrical circuit theory. The frequency of pressure changes must be kept under a certain value, because the resonance frequencies of such coupled systems can be much lower than the characteristic frequencies of their single parts. When using hard pressure-indicating devices (piezoelectric elements) instead of soft membranes, the frequency of pressure changes can be much higher. Long elastic pipes should be avoided, especially at higher pressures; the connecting lines between the receiving and indicating element should be as short as possible and their diameter not too small. When measuring pressure in narrow pipes, the diameter of the connecting pipe should be adapted for optimum damping of the system. Author concludes with some critical remarks and indications on the limits of applicability of his scheme.

A. Kuhelj, Yugoslavia

3877. Deffet, L., and Trappeniers, N., Manometric balances (in French), *Mém. artill. fr.* **128,** 4, 893–947, 1954.

3878. Woodman, E. H., Pressure cells for field use, *Wwys. Exp. Sta. Bull.* no. 40, 1–33, Jan. 1955.

Author describes pressure transducers developed to measure earth (soil-mass), hydrostatic (pore-water), and hydrodynamic pressures. Also described in a more general manner are application problems and necessary associated equipment. The transducers have four active strain gages bonded to the inner surface of their pressure-sensitive diaphragms. Since long-term stability under varying adverse conditions is considered a major requirement, considerable attention is given to problems of corrosion resistance, temperature compensation, moisture proofing, etc.

J. V. Becker, USA

3879. Acum, W. E. A., and Garner, H. C., Approximate wall corrections for an oscillating swept wing in a wind tunnel of closed circular section, *Aero. Res. Counc. Lond. curr. Pap.* 184, 23 pp., Jan. 1954, published 1955.

The oscillatory interference upwash for a circular tunnel is derived from the corresponding steady upwash. Corrections to measured derivatives of a slowly pitching wing are calculated by Multhopp's lifting-surface theory. A satisfactory approximate method using interference parameters for a small wing is given, and an extension to rectangular tunnels is suggested.

From authors' summary

3880. Wyker, H., Charts for the estimation of the permissible humidity in supersonic wind tunnels, *Publ. sci. tech. Min. Air. France* no. 123, 17 pp., 1955.

Charts are derived for the permissible humidity and the condensation Mach number as a function of stagnation temperature and pressure for supersonic wind tunnels with mean temperature gradients of 1 C/cm, 10 C/cm, and 30 C/cm if the pressure rise over the condensation shock is allowed to be 1/2%, 1%, 2%, or 5%.

An approximate method of calculation is given for the pressure rise over an extended region of condensation.

From author's summary

3881. **Street, R. E., The intermittent supersonic wind tunnel,** *Trend Engng. Univ. Wash.* **7,** 3, 17–20, July 1955.

3882. **Strom, G. H., and Halitsky, J., Important considerations in the use of the wind tunnel for pollution studies of power plants,** *Trans. ASME* **77,** 6, 789–795, Aug. 1955.

See AMR **8,** Rev. 783.

3883. **Miner, I. O., The Dall flow tube,** ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-139, 7 pp.

A primary flow-metering device which has been in use in England for some time has been thoroughly investigated to determine its characteristics. The results of this investigation are presented herewith. The outstanding characteristic is an amazingly high metering differential in comparison with the head loss engendered.

From author's summary

3884. **Dressler, R. F., Turbulent flow in shock tubes of varying cross section,** *J. Res. nat. Bur. Stands.* **53,** 4, 253–260, Oct. 1954.

The complete, centered rarefaction wave in a one-dimensional unsteady flow is investigated for tubes of variable area or with skin friction but without heat-transfer effects. (The title of the paper does not describe its contents very aptly.)

Deviations from an ideal flow are noted and several examples of modified flows are considered and discussed.

The reviewer would like to draw attention to the following additional relevant reference: "A theory for predicting the flow of real gases in shock tubes with experimental verification," by R. L. Trimpi and N. B. Cohen [*NACA TN* 3375].

I. I. Glass, Canada

3885. **Chabai, A. J., and Emrich, R. J., Measurement of wall temperature and heat flow in the shock tube,** *J. appl. Phys.* **26,** 6, 779–780, June 1955.

3886. **McGinn, J. H., Observations on the radial flow of water between fixed parallel plates,** *Appl. sci. Res.* (*A*) **5,** 4, 255–264, 1955.

Dye filament techniques were employed to investigate streamline configurations for both converging and diverging radial flow. Inherent characteristics of diverging flow are the boundary-layer separation phenomena and the formation of axially symmetric vortex sheets. The onset of boundary-layer separation is predicted from a dimensionless stability parameter which is derived from a semiempirical expression found to be in approximate agreement with wall pressure data. For flows significantly in excess of the critical rate, disturbance oscillations were observed to amplify and generate eddies. At very high rates of diverging flow, both steady-state and transient cavitation were observed. These phenomena are closely linked with the vortex formations. In contrast, converging flow retained a laminar character up to the highest rate of flow attainable.

From author's summary by H. J. Allen, USA

3887. **Lambourne, N. C., and Pusey, P. S., Some visual observations of the flow over a sweptback wing in a water tunnel, with particular reference to high incidences,** *Aero. Res. Counc. Lond. curr. Pap.* no. 192, 7 pp., 1955.

An exploratory and solely qualitative investigation has been made consisting of visual observations of the flow over a small sweptback wing. The tests were of necessity restricted to low Reynolds number (about 10^5 based on mean chord). Visualization was effected by two techniques, namely, (1) the addition of small aluminum particles to the water, and (2) the introduction of air into the stream close to the model. In addition, the surface patterns produced by the flow after the wing had been coated with oil were obtained.

Attention has been mainly concentrated on the type of flow that exists at high incidence. This flow is characterized by a flat horn-shaped region of separated flow expanding in extent over the suction surface from a position inboard near the leading edge. A "part-span" trailing vortex has been revealed and appears to be a continuation of a discrete vortex situated in the separated region.

From authors' summary

3888. **Von Hansen, M., Significance of the techniques of fluid flow for the iron furnace industry** (in German), *Stahl u. Eisen* **75,** 7, 401–410, Apr. 1955.

Thermodynamics

(See also Revs. 3591, 3612, 3626, 3628, 3831, 3832, 3833, 3854, 3867, 3876, 3880, 3882, 3902, 3903, 3904, 3916, 3927)

3889. **Samoĭlovich, A. G., Thermodynamics and statistical physics [Termodinamika i statisticheskaya fizika],** Moscow, Gosud. Izd. Tech.-Teor. Lit., 1953, 439 pp.

An extended survey of the general analytical foundations of thermodynamics and applied statistical mechanics is presented. The first part, entitled "Fundamental principles of thermodynamics," provides an intensive and comprehensive mathematical development of the first and second laws. The role of equilibrium states is clearly emphasized and sufficient flexibility is provided to allow for many types of thermodynamic displacements and forces. The second law is introduced by a consideration of Pfaffiam forms in the Caratheodory manner and is subsequently re-examined from the viewpoint of the Carnot cycle. The various relations among the thermodynamic functions are considered in relation to maximum work and equilibrium. The thermodynamics of dielectrics, magnetism, and electrochemistry is presented. Brief mention is made of the nature of irreversible processes in relation to the Clausius inequality.

The second part, "Fundamental principles of statistical physics," provides a conventional systematic development of equilibrium statistical distributions leading to the identification of the state sum, thermodynamic probability, and thermodynamic temperature. The relations between the probability distributions and the thermodynamic functions are emphasized.

Part three, "Some applications of statistical physics to the investigation of classical systems," develops conventionally such items as the virial equation of state for imperfect gases, the Langevin function for dielectric polarization, second-order transition phenomena, and the fundamentals of the thermodynamics of electric and magnetic fields.

The last part, "Quantum statistics," develops the heat capacity for a simple harmonic oscillator as occurring in metals and gases. The Fermi-Dirac and Bose-Einstein statistics are developed and applied to the photon and electron gases. A general formulation is provided for the third law or Nernst heat theorem. Throughout, the treatment is largely analytical and consistent with other current treatments. Frequent reference is made to Engels, Marx, and Lenin.

N. A. Hall, USA

3890. **De Boer, J., and Bird, R. B., Quantum corrections to the transport coefficients of gases at high temperatures,** *Physica* **20,** 4, 185–198, Apr. 1954.

The WKB method is applied to the quantum-mechanical formulation of the transport coefficients. The use of the lowest order terms in the WKB expansion of the phase shifts gives the

classical formulas for the transport coefficients. Higher-order terms in the expansion yield expressions for quantum corrections to the transport coefficients proportional to even powers of Planck's constant. Calculations for an inverse twelfth-power potential indicate that the first quantum correction is of the same order of magnitude as the precision of experimental transport coefficient measurements. From authors' summary

3891. **Morgenstern, D., Analytical studies related to the Maxwell-Boltzmann equation,** *J. rational Mech. Anal.*, **4**, 4, 533–555, July 1955.

The existence and uniqueness of solutions to an integrodifferential equation related to the Maxwell-Boltzmann equation are proved under quite general conditions. The trend of spatially homogeneous solutions to the Maxwell distribution is investigated. The basic equation which is treated differs from the Maxwell-Boltzmann equation in the inclusion in the collision term of a weighting function taken over the space from which the colliding molecule originates. Such a modification would seem to have physical plausibility; however, the macroscopic gas dynamic equations do not, in general, follow from this modified equation, as they do from the classical Maxwell-Boltzmann equation.

S. A. Schaaf, USA

3892. **Bartels, J., Thermodynamics of supercritical-pressure steam-power plants,** *Trans. ASME* **77**, 5, 705–714, July 1955.

See AMR **8**, Rev. 1797.

3893. **Michels, A., Wassenaar, T., and Wolkers, G. J., Thermodynamical properties of air for temperatures between +75° and −170°C and pressures up to 1200 atmospheres,** *Appl. sci. Res.* (*A*) **5**, 2/3, 121–136, 1955.

The thermodynamical properties of air are calculated as a function of pressure, in the temperature range from 75 to −170 C, from the compressibility isotherms published previously. Part of the two-phase region is included. Since the experimental data were limited down to −155 C, some extrapolations were necessary for the lowest temperature region.

From authors' summary

3894. **Bett, K. E., and Newitt, D. M., The critical evaluation of compression data for liquids and a revision of the isotherms of mercury,** *Brit. J. appl. Phys.* **5**, 7, 243–250, July 1954.

It is shown that Hudleston's equation represents liquid compression data at least as accurately as Tait's equation, and the straight line isotherms obtained are more convenient for the estimation of random experimental errors. The equation may also be used to extrapolate and interpolate measurements over a large *P-T* region.

Revised values for the isothermal compression of mercury from −30 to 150°C and up to 12,000 kg/cm² have been obtained by using the equation to correlate existing measurements with more recent sound-velocity determinations. Some thermodynamic derivatives for mercury are also calculated.

From authors' summary

3895. **Bloomer, O. T., Eakin, B. E., Ellington, R. T., and Gami, D. C., Thermodynamic properties of methane-nitrogen mixtures,** *Inst. Gas Technol. Res. Bull.* 21, 53 pp., Feb. 1955.

3896. **Armstrong, G. T., Goldstein, J. M., and Roberts, D. E., Liquid-vapor phase equilibrium in solutions of oxygen and nitrogen at pressures below one atmosphere,** *Nat. Bur. Stands. misc. Publ., Rep.* no. 3921, viii + 26 pp., Jan. 1955.

A cryostat and equilibrium vessel together with auxiliary apparatus for establishing equilibrium between liquid and vapor phases of solutions of low boiling material by a circulation method is described. The equilibrium vessel incorporates a novel liquid sampling device. Vapor and liquid compositions and total vapor pressures of solutions of oxygen and nitrogen were measured along isotherms at 77.5, 70, and 65 K. The activity coefficients of nitrogen and oxygen may be represented by equations of the form

$$(RT/V_{N_2})\log_e \gamma_{N_2} = A_{12}\phi^2_{O_2} \text{ and } (RT/V_{O_2})\log_e \gamma_{O_2} = A_{12}\phi^2_{N_2}$$

in which A_{12} in cal/cm³ mole has the values 1.22 at 77.5, 1.38 at 70, and 1.47 at 65 K. The deviations of the solutions from ideality are much less than are to be expected of regular solutions, in which the interaction energy between unlike molecules follows a geometric mean law. The data are not entirely consistent with the assumption that molar volumes are additive in the solutions. In an appendix, a study of the vapor pressure of nitrogen is described. From authors' summary

3897. **Pattison, J. R., The enthalpy and specific heat of iron and steel. A critical survey of the methods of determination,** *J. Iron Steel Inst. Lond.* **180**, part 4, 359–368, Aug. 1955.

A short description is given of the various methods for the measurement of the enthalpy and specific heat of iron and steel, and the available experimental data for pure iron are compared and criticized. A table of the true specific heats up to 1000 C and the heat contents up to 1400 C is compiled from the selected data. Above 1400 C, where insufficient data are available for a reliable estimation of total heat content, it is suggested that the position could be clarified by further experimental work. In the meantime it is proposed that the most reliable figure for the latent heat of melting of iron is 64.4 cal/g as obtained by Oberhoffer and Grosse, which is supported by calculations from the depression of the freezing point.

The direct determination of the total heats for steels up to the melting range has only been carried out for one steel, so that a considerable amount of work is necessary in this field.

From author's summary

3898. **Hodgins, J. W., and Hoffman, T. W., The storage and transfer of low potential heat. 1. Glauber's salt as a heat storage material,** *Canad. J. Technol.* **33**, 4, 293–302, July 1955.

A study has been made of the variables affecting the storage of low potential heat as the heat of fusion of Glauber's salt. The geometry of the container was determined as the result of preliminary experiments, using a moving transfer surface. Extensive experiments with the final design yielded the following information: (*a*) Low over-all efficiency is the result of segregation of phases as crystal growth proceeds. (*b*) Short heat paths in the exchanger are essential to keep thermal resistance at a minimum. (*c*) The crystal growth rate in this system is the rate governing process once phase isolation has occurred. (*d*) Over-all heat-transfer coefficients are in the order of 2 Btu/hr (sq ft) (° F).

From authors' summary

3899. **Broer, L. J. F., Pressure effects of relaxation and bulk viscosity in gas motion,** *Appl. sci. Res.* (*A*) **5**, 1, 55–64, 1954.

A comparative study is made of the pressure effect of relaxation and bulk viscosity in stationary flow. It is shown that both stagnation pressure defects (Kantrowitz effect) and pressure distribution in small nozzles in principle constitute methods for distinguishing between the two theories. A discussion of the experimental data on carbon dioxide shows that, in this case, only the relaxation interpretation is possible.

From author's summary by M. J. P. Musgrave, England

3900. Moori, H., On the theoretical value of the coefficient of contraction for the axially symmetrical orifice, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 285–288.

Author calculates the coefficient of contraction (in three dimensions) for the axially symmetrical orifice using the equation of momentum and assuming the orifice as a distribution of sinks. Distribution is given in accordance with the flux distribution.

It results that coefficient of contraction for the orifice cannot exceed 0.598. Previous determinations with different methods gave 0.60–0.62. G. Supino, Italy

Heat and Mass Transfer

(See also Revs. 3628, 3663, 3664, 3665, 3726, 3727, 3728, 3729, 3743, 3744, 3777, 3783, 3784, 3842, 3849, 3851, 3885, 3892, 3893, 3894, 3896, 3897, 3898, 3932, 3933, 3948, 3949)

3901. Rudiger, Von O., and Dietze, H. D., Measurement of thermal conductivity according to Diesselhorst (in German), *Tech. Mitt. Krupp* **13,** 3, 56–61, July 1955.

Kohlrausch proposed and Diesselhorst developed the following method for measuring heat conductivity of metals: A sample of the material is heated internally by an electric current, and the steady temperature field for certain prescribed boundary conditions is measured. From it the ratio of heat conductivity to electric conductivity (Wiedemann-Franz number) can be calculated, and an additional measurement of the last property determines the heat conductivity. Diesselhorst's method is based on the assumption that the electric resistance is linear in the range of measurements. Present paper replaces this by the assumption that electric conductivity and Wiedemann-Franz number are linear functions of temperature.

Derivation of calculation procedure on this basis and example of such a measurement are presented.

E. R. G. Eckert, USA

3902. Boggs, J. H., and Sibbitt, W. L., Thermal conductivity measurements of viscous liquids, *Indust. Engng. Chem.* **47,** 2, 289–293, Feb. 1955.

Successful heat engines of high specific output rely in increasing instances on fuels, oxidizers, coolants, or working fluids having unusual Prandtl numbers or Prandtl numbers which vary over wide ranges with temperature. Unfortunately, forced-convective heat-transfer measurements with many of these liquids can be experimentally troublesome and sometimes extremely hazardous. However, the necessary heat-transfer design data can be conveniently obtained by substituting easily handled, "tailor-made" liquids covering the required Prandtl number range. The fluid properties of possible substitute liquids are, therefore, of more than intrinsic interest.

Using the concentric cylinder technique, authors have obtained thermal conductivity data and thereby established Prandtl numbers ranging from the order of unity to 1×10^9 for several viscous aqueous solutions, hydrocarbon polymers, and silicone polymers of known viscosities and specific heats. Dependence of thermal conductivity upon temperature was obtained from about 80 F to about 170 F with the aqueous solutions, and up to 260 F with the polymers. Authors found that solutions of gelatin or methyl cellulose in water had very nearly the same thermal conductivity as pure water in all concentrations, but that the increase with temperature was slightly more rapid than water. The hydrocarbon polymers (Esso Vistanex, Orenete, and Indepol polybutene) had about $^1/_5$ the thermal conductivity of water and slightly positive temperature coefficient, and the dimethyl silicone polymers had conductivities about $^1/_4$ that of water, which decreased strongly with temperature. Authors estimate errors in primary measurements as less than $\pm 2\%$.

H. A. Stine, USA

3903. McIntosh, G. E., Hamilton, D. C., and Sibbitt, W. L., Rapid measurements of thermal diffusivity, *Trans. ASME* **76,** 3, 407–410, Apr. 1954.

Title measurements (less than 1 hr) are desirable to avoid effects of annealing, etc. Rods were cyclically heated at one end and temperature waves at two stations along length were harmonically analyzed. Phase lags were used to calculate diffusivities vs. temperature from 455 to 675 R. Respective approximate values were for iron, 0.65 to 0.82 ft²/hr; zirconium, 0.41 to 0.31; titanium, 0.25 to 0.21, stellite 0.09 to 0.15 (read from graph). Authors attribute high errors (7%) to analysis, but do not detail method for eliminating radiation errors. Others have eliminated radiation term by two sets of measurements (introducing other errors) or use of both phase and decrement data [AMR **7,** Rev. 2286]. Authors conclude that Forbes method is better, but discussion by Danielson, Sidles, and Pearson questions this conclusion and proposes another method. W. C. Shaw, USA

3904. Nekhendzi, E., Iu., Determination of the thermal capacity and conductivity of metals in transient (heating or cooling) regime (in Russian), *Zh. tekh. Fiz.* **24,** 8, 1428–1440, Aug. 1954.

Paper considers method of determination of thermal properties (capacity, conductivity, diffusivity) of metals at high temperatures, somewhat extending to metals the methods of transient regime with its inherent advantages (rapidity, small temperature interval, accurate surface heat-transfer coefficient determination) over steady-state methods.

Author defines as regular-transient regime the straight line portion of heating (cooling) curve in semilog coordinates, and uses its slope (thermal properties function) as basis for determination of diffusivity, capacity, and conductivity. Heat-transfer coefficient is determined from control sample. Sphere is used for experiment to reduce the size of the test rig. Method is limited to small temperature differences to assure thermal properties constant during experimental runs. Discussion of determination errors is included.

Paper presents interesting modification of experimental methods and setups used in the field for materials other than metals.

H. Hurwicz, USA

3905. Bryson, R. A., Convective heat transfer with light winds, *Trans. Amer. geophys. Un.* **36,** 2, 209–212, Apr. 1955.

A convection cell of horizontal radial symmetry is envisaged with an inverted funnel-shaped core containing rising air of constant temperature T_r surrounded by sinking air of temperature T_e. By assuming that the vertical acceleration of the lighter air is proportional to the difference in temperature between the core and its environment, and supposing that no entrainment occurs and that the rising air is of constant density, author derives a formula for the radius of the inverted funnel-shaped column at any height in terms of the temperature difference $T_r - T_e$ and the net heat flux induced by the convection cell. By making the additional assumption that the heat flux is independent of height, author finds that the lapse rate of the *mean* temperature gradient varies inversely as the 3/2 power of the height. This is compared with measurements, application being limited to conditions of calm or light winds. Author identifies T_e and T_r in actual measurements with the values of the modes in the observed bimodal frequency of occurrence diagram of temperature.

Reviewer feels that one of the weak points in the quantitative application of the author's formula is in the evaluation of R_0, the over-all radius of the convection cell. The definition of the mean temperature is rather critically dependent upon this radius.

R. O. Reid, USA

3906. Wilson, D. G., and Pope, J. A., Convective heat transfer to gas turbine blade surfaces, *Proc. Inst. mech. Engrs.* **168,** 36, 861–874, 1954; *Engineer, Lond.* **198,** 5144, Aug. 1954.

The local heat-transfer coefficients between the surface of a gas turbine blade in cascade and the air in a low-speed wind tunnel are determined with an improvement of the method of Bryant, Ower, Halliday, and Falkner [1928, *Aero. Res. Counc. Rep. Mem.* no. 1163], i.e., by measuring, when a uniform surface temperature was reached, the power input to electrically heated thin strips placed upon the surface of the model blade. In the laminar boundary layer the results give good agreement with the theory of Squire (1942), but the predictions in the regions of turbulent boundary-layer flow, particularly under negative pressure gradients, leave, as authors say, much to be desired.

C. Codegone, Italy

3907. Malkus, W. V. R., Discrete transitions in turbulent convection, *Proc. roy Soc. Lond.* (*A*) **225,** 1161, 185–195, Aug. 1954.

Author has carefully measured the heat transport in a fluid between two horizontal plates 10 cm in diam spaced from 0.050 to 8.000 in. apart. A quasi-equilibrium system was used in which heat loss was minimized and the decay rate in temperature differential was restricted to values less than 0.06% per sec. Discrete transitions in heat transfer were observed at six values of the Rayleigh number λ between 1700 and 1,000,000 when $\lambda = \alpha g \beta_0 d^4/K\nu$ (α is thermal expansion coefficient of fluid, K thermal conductivity, β_0 temperature gradient, g acceleration of gravity, ν kinematic viscosity, d distance between surfaces).

The transitions have been attributed to changes in convection from laminar to turbulent and to various modes of turbulent motion. Surprisingly good correlation of the transition points has been found with values computed by a method which assumes a constant temperature gradient. An interesting observation was the negligible effect on heat transfer of a vertical divider which was noted to change the horizontal flow pattern.

Reviewer believes paper is a valuable contribution to the literature.

R. H. Eustis, USA

3908. Malkus, W. V. R., The heat transport and spectrum of thermal turbulence, *Proc. roy. Soc. Lond.* (*A*) **225,** 1161, 196–212, Aug. 1954.

A theoretical analysis is made of turbulent convection of heat between two horizontal conducting surfaces. Author writes heat-transport equation in terms of conduction and contribution due to convection. He expresses the eddy convection term as a Fourier series terminated after n_0 terms. A solution, not shown to be unique, is suggested which permits expression of coefficients in terms of n_0. It is suggested that the modes of motion are characterized by the value of n_0 which is further related to a minimum eddy size effective in heat transport. Comparison with the discrete transitions of heat transport found in the author's experimental study (see preceding review) shows agreement within 10%.

An extension of the stability analysis of Pellew and Southwell shows that the assumption of a constant thermal gradient was sufficiently accurate in predicting the Rayleigh number for transition of modes of motion in natural convection.

Mean convective velocities and temperature are computed and the velocities are compared with experimental data (op. cit.). The correlation is not conclusive but is within the possible experimental error of about 25%.

R. H. Eustis, USA

3909. Goldmann, K., Heat transfer to supercritical water and other fluids with temperature-dependent properties, Nuclear Engng. Part I, *A. I. Ch. E. Chem. Engng. Progr. Symp. Series* no. 11, vol. 50, 105–113, 1954.

A method of analysis is proposed for the prediction of heat transfer and pressure drop in fluids with temperature-dependent properties in fully developed turbulent flow. The method is based on the Reynolds analogy between momentum exchange and heat exchange. The method utilizes the concept of the universal velocity distribution through the boundary layer, considering the ratio of the thermal and momentum eddy diffusivities to be unity and that the shear stress in the boundary layer is a constant equal to the wall value. The method is similar to that described by Deissler for such systems but differs in that the method described requires the turbulent mixing process to be a function of the fluid properties at the point in question being unaffected by the property variation in the near vicinity of the point. Comparison of the calculation made in accord with the present method and calculations made by the method proposed by Deissler for the same system give results which are 15% lower than those obtained by Deissler method. Authors state that Deissler's method gives results which are 10% higher than comparative experimental results, but compa-·on with data is not shown in paper. It would seem to reviewer that such variations as 15% may well occur in the experimental effort and that the difference in the two methods might well be within the experimental error. Appendix to paper gives interesting tabulation of thermodynamic and transport properties for water at 5000 psia.

R. M. Drake, Jr., USA

3910. Reese, B. A., and Graham, R. W., Heat transfer and frictional pressure drop characteristics of white fuming nitric acid, *Jet Propulsion* **24,** 4, 228–233, 236, July 1955.

See AMR **7,** Rev. 4025.

3911. Gardner, A. J., An introduction to the thermal problems of turbojet engines for supersonic propulsion, *Trans. ASME* **77,** 5, 715–720, July 1955.

See AMR **8,** Rev. 1506.

3912. Marco, S. M., and Han, L. S., A note on limiting laminar Nusselt number in ducts with constant temperature gradient by analogy to thin-plate theory, *Trans. ASME* **77,** 5, 625–630, July 1955.

See AMR **8,** Rev. 812.

3913. Kavanau, L. L., Heat transfer from spheres to a rarefied gas in subsonic flow, *Trans. ASME* **77,** 5, 617–623, July 1955.

See AMR **8,** Rev. 813.

3914. Makowski, J., and Whitney, V. L., Jr., Personnel and equipment cooling in supersonic airplanes, *Trans. ASME* **77,** 5, 741–746, July 1955.

Cooling of crew compartments and electronic equipment becomes more important and, at the same time, more difficult as airplane speeds increase. A sharp increase in capacity required from the cooling system takes place when the surrounding air becomes too hot to be a convenient direct heat sink. The successful use of water vaporization permits the design of compact cooling units which satisfy the requirements of supersonic airplanes.

From authors' summary

3915. Srivastava, B. N., and Srivastava, R. C., Investigation of the performance of thermal diffusion column, *Physica* 20, 4, 237–242 Apr. 1954.

Authors extend the theory of the thermal diffusion column as developed by Furry and Jones from the linear case for the thermal diffusion constant α to the case when $\alpha = A - B'/T$, where A and B' are constants and T is the temperature. The formulas developed were tested by comparison with experimental data on methane, and the agreement between them was found to be quite satisfactory. E. J. Scott, USA

3916. Zwick, S. A., and Plesset, M. S., On the dynamics of small vapor bubbles in liquids, *J. Math. Phys.* 33, 4, 308–330, Jan. 1955.

Since Rayleigh's calculation of the collapse of an empty cavity in water, several writers have attempted related problems using more realistic assumptions. The motivation for these attempts has come from various fields, but primarily from the study of hydrodynamically induced cavitation. The problems are difficult because they involve the complicated interplay of a variety of physical phenomena. Not all of the factors that may play some part in describing the history of a cavity are considered in this paper. Even so, the calculations presented may be the most elaborate yet attempted.

It is assumed that the cavity remains spherically symmetric and is filled only with water vapor. The compressibility and viscosity of the water are neglected and the fluid at great distance from the bubble is assumed to be undisturbed. The vapor is assumed to be of uniform pressure and temperature and in equilibrium with the water at the boundary of the bubble. The problem is formulated in terms of equations which may be written symbolically as follows:

The first equation

$$F_1(R, p_v) = 0 \qquad [1]$$

is an equation of motion for the bubble wall and relates the time history of the radius of the bubble R and the pressure of the vapor p_v. The second equation

$$F_2[T, (\partial T/\partial r), R] = 0 \qquad [2]$$

is an approximate integration for the heat-diffusion equation, given by the authors in a previous paper, and relates the temperature T at the bubble wall to the temperature gradient $\partial T/\partial r$ at the wall and the radius R. The third equation

$$F_3[(\partial T/\partial r), R, \rho'] = 0 \qquad [3]$$

expresses the equality of the rate at which heat is diffused from the boundary and delivered by condensing vapor. This equation relates the temperature gradient $\partial T/\partial r$, the radius R, and the density of the vapor ρ'. Finally, the condition of equilibrium between the vapor and water gives the equations

$$p_v = p_v(T),\ \rho' = \rho'(T) \qquad [4]$$

i.e., the vapor density and pressure are functions only of the temperature.

In addition to the case where the temperature of the water is far below the boiling point and the vapor bubble collapses, the paper treats the case where the temperature of the water is slightly above boiling and the bubble expands. In the latter case, a small source of heat, uniformly distributed in the water, is assumed to initiate the growth of the bubble and, making use of the small variation of the temperature of the vapor, approximate analytical solutions are obtained for the various phases of the bubble growth: the initial delay period during which there is no appreciable growth, the early phase during which the bubble grows at an accelerated rate to about twice the initial radius, and the intermediate phase which carries the bubble close to the asymptotic rate of growth. The expressions obtained are evaluated for one specific case for which results are presented graphically.

The most interesting aspect of the calculation of the collapsing vapor bubble is in what light might be shed on the conditions prevailing during the final stages of collapse. Unfortunately, for several reasons the formulation of the problem is not adequate for dealing with the very last stage of the collapse. However, the results presented for one case, for which the equations were solved numerically, indicate that the limitation on the diffusion of the heat released by the condensing vapor does very little to retard the collapse of the bubble. The history of the bubble radius differs very little from that obtained by Rayleigh. In the latter stages the inward velocity of the bubble wall and the temperature of the vapor increase at very rapidly accelerating rates.

Although the question cannot be regarded as completely settled, experimental evidence has indicated that bubbles containing only vapor collapse without rebounding. The results presented in this paper tend to support this thesis in that there is no indication that the inward motion would be seriously arrested in any way.

Interest in the final stage of collapse stems from the significance of this stage in regard to the destructive effects of cavitation. A previous calculation by R. S. Silver [*Engineering*, 501–502, Dec. 1942] had indicated that the limitation on the diffusion of the latent heat released by the condensing vapor would not greatly retard the collapse of a vapor bubble nor reduce its destructive effects very materially. The present paper appears to confirm this. However, reviewer believes that the presence of the vapor may have a somewhat greater retarding effect than that obtained from consideration of the latent heat alone. This is due to a factor which appears to have been neglected in the formulation of the problem; specifically, the energy released by the compression of the vapor.

The compression of the vapor remaining in the bubble is given by $dV/dt = -V(d\rho'/dt)/\rho'$, where $V = 4/3\pi R^3$.

The rate at which heat is released by this compression is given by

$$\begin{aligned} dQ/dt &= -p_v(dV/dt) - \rho' V c_v(dT/dt) \\ &= -p_v V(d\rho'/dt)/\rho' - \rho' V c_v(dT/dt) \\ &= \rho' V[p_v(d\rho'/dt)/(\rho')^2 - c_v(dT/dt) \\ &\doteq \rho' V[(l/T) - R' - c_v](dT/dt) \doteq \rho' V\ (l/T)\ (dT/dt) \end{aligned}$$

where the last approximation is obtained by assuming the equation of state of a perfect gas $p_v = R'\rho' T$, and the Clapeyron-Clausius equation for liquid-vapor equilibrium $dp_v/dt = p_v l R' T^2$; R' is the gas constant, c_v is the specific heat, and l is the latent heat of vaporization, all per unit mass, and T is to be given as absolute temperature. Since l is substantially greater than $R' + c_v$, the compression always releases heat.

In the formulation of the problem the heat diffused into the water is equated to the latent heat released by condensation, so that it is tacitly assumed that the heat released by compression, $-dQ/dt$, vanishes. But this cannot be true, for then the temperature would have to be constant. Therefore, it appears to the reviewer that the rate that heat is released by compression should be added to the rate that heat is released by condensation in formulating Eq. [3]. The ratio of the magnitudes of these rates is given approximately by

$$\rho' V(l/T)(dT/dt)/l(d\rho' V/dt) = (d/dt)\log T/(d/dt)\log \rho' V \qquad [6]$$

i.e., the ratio is equal to the ratio of the relative rates of change

of temperature and mass. The results given in the paper for the collapse of the bubble indicate that the rate of release of heat by compression would not be negligible in comparison to the rate of release of latent heat by condensation. L. Pode, USA

3917. Kramers, H., Cappelle, E. F., and Van Der Schraaf, E. E., Heat transfer in a film evaporator (in Dutch, with English summary), *Ingenieur* **67**, 8, 9–15, Feb. 1955.

After a brief discussion of film evaporation, a number of experimental results are presented on the rate of evaporation of various liquids in a Müller evaporator.

The results indicate that, generally, evaporation takes place from the surface of the liquid film. In that case, the heat of vaporization is supplied by heat conduction through the film which is laminar at the liquid loads encountered in practice. Additional transfer of heat by nuclear boiling on the wetted surface is only appreciable with liquids which show a strong tendency to foaming.

The main functions of the rotor in the Müller evaporator are the distribution of liquid feed, the catching and redistribution of splashes, the breaking of foam, and the removal of entrained liquid from the vapor. From authors' summary

3918. Eckert, E. R. G., and Livingood, J. N. B., Comparison of effectiveness of convection-, transpiration-, and film-cooling methods with air as coolant, *NACA Rep.* 1182, 17 pp., 1954.

Supersedes article reviewed in AMR **7**, Rev. 1286.

3919. Kelen, A., An electrically regulated thermostat for isothermal calorimetry, *Appl. sci. Res.* (*B*) **4**, 5, 309–316, 1955.

A detailed description of the construction and manner of operation of an electrically heated and regulated thermostat and equipment for isothermal calorimetry is given. The thermostat has a temperature constancy better than a thousandth of a degree per hr during long periods in the temperature interval from 450 C to 35 C, and is intended to be useful up to 550 C.

From author's summary

3920. Chambre, P. L., and Grossman, L. H., On limiting temperatures in chemical reactors, *Appl. sci. Res.* (*A*) **5**, 4, 245–254, 1955.

The heat flow in a chemical reactor of flat plate or cylindrical shape is analyzed on the basis of the Arrhenius reaction-rate expression. The analysis yields a critical design parameter which allows dimensioning of the reactor in order to maintain the reactor temperatures within narrowly prescribed limits.

From authors' summary

Combustion

(See also Revs. 3696, 3888, 3919)

3921. Pino, M. A., A versatile ignition delay tester for self-igniting rocket propellants, *Jet Propulsion* **25**, 9, part 1, 463–466, Sept. 1955.

Ignition delay is an important criterion by which self-igniting liquid rocket propellants are evaluated. An ignition delay tester which combines simplicity of construction and operation with a high degree of flexibility has been developed. Important variables, such as propellant temperature, propellant ratio, and degree of mixing, can be controlled and reproduced accurately. Screening of additives and determination of optimum fuel blends are among the uses to which ignition delay studies may be applied. The tester is a valuable tool in propellant research.

From author's summary

3922. Setchkin, N. P., Self-ignition temperatures of combustible liquids, *J. Res. nat. Bur. Stands.* **53**, 1, 49–66, July 1955.

The methods previously used for determining the ignition temperatures of liquids are briefly reviewed, and the large discrepancies in reported values are noted. Various factors which affect the determined values of ignition temperature are discussed. A practical ignition apparatus consisting in part of an insulated spherical flash, designed to provide conditions favorable to low ignition temperature values, is described, and data obtained with this apparatus on a considerable number of combustible liquids are presented. The usefulness of time-temperature curves of a thermocouple junction placed in mixtures of combustible liquid and air, as a means of studying the preignition reactions in such mixtures, is illustrated. From author's summary

3923. Wohl, K., Burning velocity of unconfined turbulent flames: Theory of turbulent burning velocity, *Indust. Engng. Chem.* **47**, 4, 825–827, Apr. 1955.

The theories of Karlovitz, Denniston, and Wells [*J. chem. Phys.* **19**, 541–7, 1951] and Scurlock and Grover [AMR **7**, Rev. 4046] are reviewed and critically compared. The latter's equations are modified to yield an expression that can be integrated for the root-mean-square displacement of the flame front with time. From a comparison of the effects of approach-stream turbulence predicted by both the theories of Karlovitz and coworkers, and Scurlock and Grover, author concludes that, with the same suppositions, the two theories lead to similar results for the steady state of the passive flame fronts. Effects of flame-generated turbulence are discussed. J. H. Grover, USA

3924. Wohl, K., and Shore, L., Burning velocity of unconfined turbulent flames: Experiments with butane-air and methane-air flames, *Indust. Engng. Chem.* **47**, 4, 828–834, Apr. 1955.

A study of flames burning above burner tubes was made and results were compared with the theories of Karlovitz, Denniston and Wells [*J. chem. Phys.* **19**, 541–7, 1951] and Scurlock and Grover [AMR **7**, Rev. 4046]. Average burning velocities for flames distorted by pipe turbulence generated by screens were determined. For methane, theory and experiment agree moderately well. With butane, the effect of approach-stream turbulence is strongly suppressed in lean mixtures and strongly augmented in rich ones. Both this insensitivity of the burning velocity to the approach-stream scale of turbulence and the observations from schlieren photographs indicate that the "flame-front scale" is independent of the approach scale. Curves of average burning velocity of butane-air flame versus approach-stream velocity are similar to those predicted by the theory of Scurlock and Grover.

The effect of approach-stream velocity and tube diameter on the turbulent burning velocity was determined. The thickness of the flame brush was measured. J. H. Grover, USA

3925. Miller, R. O., Flame propagation limits of propane and *n*-pentane in oxides of nitrogen, *NACA TN* 3520, 29 pp., Aug. 1955.

Flame propagation limits of propane and *n*-pentane in oxides of nitrogen were obtained at subatmospheric pressures in a 2-in.-diam by 48-in.-length tube. Three oxidants were investigated, namely, nitric oxide NO, nitrogen tetroxide N_2O_4, and a nearly equimolar mixture of these two oxides.

Flames propagated through all the fuel-oxidant mixtures with the limits occurring at equivalence ratios of roughly 1/3 and 3.

The minimum propagation pressure of the fuel-NO mixtures in the 2-in.-diam tube was appreciably greater than that of the fuel-N_2O_4 mixtures. The limits of the nitrogen oxides with propane at 1 atmosphere were narrower on a stoichiometric basis

than for equivalent propane mixtures with molecular oxygen and nitrogen, interpolated from published data.

Estimated flame temperatures at the lean limit were appreciably lower for the N_2O_4 and the NO-N_2O_4 mixtures than for the NO mixtures and were about the same as lean-limit temperatures of fuel-air mixtures. In general, the data attest to the relative chemical stability of NO in the hydrocarbon flames.

From author's summary

3926. Dugger, G. L., and Simon, Dorothy M., Prediction of flame velocities of hydrocarbon flames, *NACA Rep.* 1158, 10 pp., 1954.

Supersedes article reviewed in AMR **7**, Rev. 3745.

3927. Kurz, P. F., Flame stability studies with hydrocarbon mixtures, *Fuel* **34,** 3, 269–282, July 1955.

Paper is an extension of earlier work on mixtures of hydrocarbons with hydrogen, etc.

Blow-off limits for lean mixtures were measured using a bunsen-type burner and two "vortex" burners specially designed for use with very fast-burning fuels. Various binary mixtures of paraffins, isobutane, ethylene, and propylene, butadiene, and acetylene and a ternary mixture of ethane, propane, and propylene were studied.

Tests were made using an inert gas, argon, for blow-off as well as air. Results were in agreement with those for "air stability."

Results for the three burners and for both binary and ternary mixtures were in good agreement with a simple mixing formula. Hydrocarbon fuels were thus found to be compatible, or non-interfering, in flames of lean mixtures. Blow-off limits for mixtures can be calculated quite readily from properties of the individual fuels.

R. C. Anderson, USA

3928. Bjerklie, J. W., A combustor analysis method evolved from basic flame stability and fuel distribution research, *Jet Propulsion* **25,** 5, 227–234, May 1955.

Author takes DeZubay's [*Aero Digest* **61,** pp. 54, 102, 1950] correlation of experimental fuel/air ratios for blowout of disk baffle stabilized flames with a stability parameter varying with flow velocity, combustion pressure, and baffle diameter, and Longwell's [*Indust. Engng. Chem.* **45,** p. 667, 1953] theory of fuel distribution from nozzles injecting into an airstream. He discusses their combined application to the development of ramjet combustions with multinozzle injection upstream of a gutter-type baffle, and presents a method of calculation of local fuel/air ratios in flows of nonuniform velocity.

No new experimental data are given, but author states that use of this stability analysis has improved performance and reduced development time of afterburners and ramjet engines.

G. K. Adams, England

3929. Potter, A. E., Jr., and Berlad, A. L., A thermal equation for flame quenching, *NACA TN* 3398, 18 pp., Feb. 1955.

Utilization of two separate rate-controlling reactions—(1) that between active particles and fuel molecules, and (2) that between oxygen and fuel molecules—results in two thermal equations describing critical flame-quenching distance. One empirically derived constant was necessitated.

Comparison of predicted results to experimental data shows active particle-fuel molecule reaction control to be more generally satisfactory than oxygen-fuel. Both derived equations give encouraging results for propane-oxygen-nitrogen systems. Authors conclude that shortcomings of the relationships in the lean and rich regions can be minimized by an improvement in the choice of reaction kinetics.

E. S. Starkman, USA

3930. Arenson, D. L., McClow, J. H., Jr., and Wiant, H. W., Rocket powered test vehicles, *Jet Propulsion* **25,** 9, part 1, 441–445, 466, Sept. 1955.

In the design and development of present-day aircraft and missile equipment, it is frequently essential to obtain tests of particular components at supersonic speeds and high altitudes. For these purposes a series of rocket-powered test vehicles have been developed for use on the Free Air Facility Track at Edwards Air Force Base, Calif. These vehicles are described, the basis for their design presented, and their performance is analyzed. Rocket-powered missiles have also been used to study such problems as ejection-seat operations and recovery parachute operations at supersonic speeds. Considerations pertinent to the design of these vehicles are described and an evaluation of their performance is presented.

From authors' summary

3931. Felt, N. E., Jr., Development of a stabilization system for the Viking rocket, *Jet Propulsion* **25,** 8, 392–395, Aug. 1955.

The unconventional flight path of the Viking, viz., a high-altitude nearly vertical trajectory, results in some unusual problems in the design of an automatic stabilization system. In the present vehicle, these problems are solved by employing three separate subsystems. First, there is the motor control system which obtains corrective moments by altering the line of thrust of the liquid rocket engine. The second system, the aerodynamic roll system, employs movable tabs attached to two of the fins. Finally, there is a thrust reaction system which obtains control moments through the use of small jet motors. Design of the first two subsystems was based on the familiar frequency-response techniques, while automatic computers and nonlinear methods were required for the third system. Results of flights to date indicate that the basic approach was sound. However, experience gained on the first nine rockets has shown the need for greater emphasis on reliability, ease of adjustment, and interchangeability of system components during the early phases of the program.

From author's summary

3932. Schwarz v. Bergkampf, E., Basic general data for rotary-kiln-model computations (in German), *Zement-Kalk-Gips* **7,** 11, 424–427, Nov. 1954.

3933. Anselm, W., Model similarity studies for rotary kilns (in German), *Zement-Kalk-Gips* **7,** 11, 427–434, Nov. 1954.

3934. De Lorenzi, O., Bagasse-burning in the Mexican sugar industry, *Trans. ASME* **77,** 4, 549–559, May 1955.

Bagasse is the principal source of heat for the production of raw sugar. Early furnace designs were satisfactory from the standpoint of operation and steam output during the period when labor was plentiful and this by-product fuel was assigned little or no value. Rising costs of fuel, equipment, repairs, and wages, however, have altered this picture materially. Older plants consisted in a multiplicity of small boilers with refractory hearth-type furnaces. Operating efficiency was low, and steam output dropped during long periodic hearth-cleaning periods. These designs are definitely outmoded through the rapid advances which have been made during the past 10 years. Newer designs of steam-generating units now incorporate spreader stokers, water-cooled furnaces, bent-tube boilers, superheaters, air heaters, and bagacillo-return systems. They have more flexibility, greater capacity, higher efficiency, and are less subject to operational

interruption. Many units of this type have now been in operation for considerable periods of time in practically all of the world's raw-sugar-producing areas. It is the purpose of this paper to discuss, primarily, the operating characteristics of this new design as experienced with installations in Mexico. Comparative data also are presented to stress normal operating differences between hearth-type and spreader-fired unit.

From author's summary

Acoustics

(See Rev. 3755)

Soil Mechanics, Seepage

(See also Revs. 3647, 3648, 3681, 3719, 3721, 3800, 3810, 3878)

3935. Rocha, M., New possibilities of solving problems in soil mechanics with the aid of models (in Portuguese), *Bol. ord. Engenheiros* **4**, 13, 1–14, July 1955.

As in other fields of applied mechanics, especially in structural analysis, the use of models for study and solution of problems in soil mechanics promises greater economy and safety of structures in which soil conditions are important factors, as, e.g., foundations, earth-filled dams, retaining walls, etc. In general, a soil consists of solid particles with cells filled with liquid material subject to percolation under pressure. These conditions are expressed analytically, and conditions of similarity in models of prototypes, with and without percolation of the liquid phase are described, especially the elastic behavior of soil masses without percolation and when deformations are affected by time.

Study of one case is discussed more thoroughly in which the coefficients of permeability of the prototype are compared with those of the model. Also cases with percolation are analyzed where deformations are or are not affected by time. In some cases the materials of the prototype can be used advantageously for the construction of the models, and general indications are given on how to find materials which fufill the requirements for similarity. Model tests carried out by the author are described with emphasis on further necessary study.

J. J. Polivka, USA

3936. Nishida, Y., Theoretical considerations on the lateral friction of foundation piles (in Portuguese), *Inst. Pesq. Technol. São Paulo Publ.* no. 515, 17–36, 1954.

A theoretical analysis of pile forces in cohesionless soil and solution of equilibrium equation for specified conditions. Author deduces the following: (1) Bearing power by skin friction is proportional to pile radius by length squared, but is small part of actual capacity in cohesionless soil. (2) Bearing power by skin friction is mainly contributed by lower part of pile. Variation in skin friction is not proportional to depth. (3) Normal pressure against a vertical wall is not proportional to depth. (4) Induced ground stresses due to skin friction of a pile are shown to be computable.

J. M. DallaValle, USA

3937. Danilyuk, A. M., Calculation of foundation settlement on laminated stratified soils (in Russian), *Izv. Akad. Nauk SSSR, Otd. tekh. Nauk* no. 6, 87–96, June 1954.

Approximate computation of rigid foundation settlement on laminated stratified soil of variable compressibility (including rock surface) starts with formulas for settlement of equivalent layers of homogeneous elastic foundation. Formulas for settlement of rigid and flexible slabs are combined and trimmed in accordance with more exact solutions of other authors. Necessary coefficients for numerical computations are given. Author gives two numerical examples and points out that his solution gives as precise results as more exact ones, whereas his method is more universal. In introduction, a review of solutions used in USSR is given.

V. Menel, Czechoslovakia

3938. Eastwood, W., The bearing capacity of eccentrically loaded foundations on sandy soils, *Struct. Engr.* **33**, 6, 181–187, June 1955.

Tests carried out on strip footings indicate that the usual practice of assuming that there is a straight line distribution of pressure under an eccentrically loaded foundation, and that the ultimate value of that pressure is the same as that under a centrally loaded foundation, is sound for footing on sand and eccentricities up to $b/6$. An alternative hypothesis put forward by Meyerhof, in which the ultimate load for an eccentrically loaded footing is assumed to be equal to that for a footing of width equal to the actual width minus twice the eccentricity, does not agree so well with some of the experiments. Footings on sand which are restrained from slipping sideways have no definite ultimate load whether centrally or eccentrically loaded, there being no sudden drop of bearing power when slip surfaces are formed. When only partial restraint against lateral movement is allowed, there may be a well-defined ultimate load somewhat higher than that obtained with no lateral restraint of the footings.

From author's summary

3939. Flow through porous media, *Indust. Engng. Chem.* **46,** 6, 1163–1246, June 1954.

The following eleven papers are presented: Comings, E. W., Pruiss, C. E., and DeBord, C., Continuous settling and thickening; Thompson, D., and Vilbrandt, F. C., Settling of solids in phosphate tailing; Happel, J., and Byrne, B. J., Steady motion of a sphere in a cylindrical tube; Happel, J., and Epstein, N., Cubical assemblages of uniform spheres; Cunningham, G. E., Broughton, G., and Kraybill, R. R., Flow through textile filter media; Silverblatt, C. E., and Dahlstrom, D. A., Moisture content of a fine-coal filter cake; Dombrowski, H. S., and Brownell, L. E., Residual equilibrium saturation of porous media; Kocatas, B. M., and Cornell, D., Gravity drained soybean flake beds; Leva M., Lucas, J. M., and Frahme, H. H., Mechanical operation of packed towers; Sakiadis, B. C., and Johnson, A. I., Generalized correlation of flooding rates; Michaels, A. S., and Lin, C. S., Permeability of Kaolinite.

Specialists in production of petroleum from underground reservoirs, filtration of chemicals, clarification of liquids, fluidization of solids, hydraulics of suspensions, extraction of essential oils, absorption, and distillation have many things in common.

This symposium brought together experts from various fields of specialization to present concepts and techniques that could interest all. The physical relationships involved range from the settling of individual particles or groups of particles through quiescent liquids to countercurrent flow of liquids and gases through fixed beds.

From J. L. York's introduction

3940. Ohji, M., A contribution to the theory of the seepage through an earth dam, *Rep. Res. Inst. appl. Mech. Kyushu Univ.* **3, 9, 1–10,** Apr. 1954.

Some calculating formulas are proposed for the seepage through a two-dimensional earth dam on impermeable ground, making use of the Cauchy theorem in function theory together with other simplifying assumptions. The method seems to be a general one, but only the cases of rectangular and trapezoidal dams with a horizontal base are calculated here, for both of which the experimental and theoretical data are available. As is seen from the numerical examples, these formulas give at least the correct order

of magnitude for the total flux and the height of the seepage surface. Incidentally, the legitimacy of the Dupuit-Forchheimer-Muskat formula for the total flux of a rectangular dam is pointed out. From author's summary

3941. Carlson, R. W., Permeability, pore pressure and uplift in gravity dams, *Proc. Amer. Soc. civ. Engrs.* **81,** Separ. no. 700, 17 pp., May 1955.

3942. Arkhangel'skiĭ, V. A., Interaction of a stratum and a well during the flow of gasified petroleum (in Russian), *Inzhener. Sbornik. Akad Nauk SSSR* 19, 149–158, 1954.

Micromeritics

(See also Rev. 3941)

©3943. Sokolovskiĭ, V. V., Statics of granular media [Statika sypucei sredy], 2nd ed., Moscow, Gosud. Izd. Tekh.-Teor. Lit., 1954, 275 pp. 10.50 rubles.

In this second edition, the material of the first edition (published in 1942) has been completely rearranged and much new material has been added. In chap. 1, the classical theory of limiting states of equilibrium is developed. The problem is treated in a purely statical manner by means of the equations of equilibrium and a limiting condition on stress. Since no attempt is made to formulate stress-strain relations, the relevant results of modern limit analysis cannot be used [see, e.g., D. C. Drucker and W. Prager, *Quart. appl. Math.* 10, 157, 1952, and D. C. Drucker, *J. Mech. Phys. Solids* 1, 217, 1953]. As three-dimensional problems are beyond the reach of this statical theory, the remainder of the book is devoted to the plane problem. The canonical equations for this are established. Typical boundary-value problems and numerical methods for their solution are given, and mechanical similarity is briefly discussed.

Chaps. 2 and 3 are devoted to the practical problems of the bearing capacity of foundations and the stability of banks and retaining walls. The importance of stress singularities and lines of rupture is discussed, and problems concerning stratified granular media are presented. Chaps. 4 and 5 treat the special cases of cohesionless and frictionless granular materials. The neglect of cohesion or internal friction often makes it possible to obtain solutions to simple boundary-value problems in closed form. The practical use of such solutions is illustrated by several examples.

The bibliography has been considerably expanded; contrary to recent Russian practice, references to non-Russian literature have not been suppressed in this revised edition.

W. Prager, USA

3944. Wellinger, K., and Uetz, H., Sliding wear, rinsing wear, and blasting wear under the influence of granular solids (in German), *VDI-Forschungheft* **449,** 21, 40 pp., Aug. 1955.

A large quantity of flat and tubular test specimens, from various materials such as steel in different grades, chill casting, cast basalt, and rubberlike substances, were tested for wear resistance against limestone, glass, coke dust, flint, river sand, quartz, garnet, corondum, silicon carbide (carborundum), and casting shots of various hardness values. The various testing setups used permitted the individual determination of the wear resulting from sliding, rinsing, and shot blasting, respectively, performed over a wide range of load conditions. Thus, it was possible to determine the influence of hardness and of structure of the materials, and also of the grain size, grain shape, hardness, and degree of moisture of the wearing agents. Furthermore, the flow rates of the wearing agents and the pressure between wearing agent and material were determined. By comparing the test results with those obtained in practical service on blast pipes and on the stirrers of gravel dredging, it was found that the results of this investigation can be safely applied in practice.

From authors' summary

3945. Jones, H. G., Davies, W. M., and Dickerson, P. D., The study of materials-handling systems by a lead-shot analogue, *J. Iron Steel Inst. Lond.* **180,** part 3, 255–262, July 1955.

Paper indicates the need for insuring that the integrated capacity of a complex system (as well as the capacity of the component units) is adequate to meet future demands.

Lead shot as a medium in a model or analog has the advantage of flowing from an orifice at a speed independent of the pressure head. From the known rates of ship discharge and estimated usings, the flow pattern through the conveyor system, screens, and bunkers associated with the blast-furnace and ore-preparation plant has been examined on the analog, and bottlenecks and surplus members have been recognized.

The merits of alternative routes for the raw materials have been evaluated and certain guiding principles, apposite to the particular installation, have been advanced. A control scheme for future operation has been developed.

From authors' summary

3946. Fischerström, N. H., Sedimentation in rectangular basins, *Proc. Amer. Soc. civ. Engrs.* **81,** Separ. no. 687, 29 pp., May 1955.

The "overflow rate" determines the highest possible sedimentation efficiency obtainable for a given sediment. In a continuous flow basin the actual efficiency is mostly considerably lower than the top efficiency because of disturbances. In this paper, author points to the dominating importance of good hydraulic properties of a sedimentation basin to avoid disturbances, even if hydraulic and sedimentation efficiency do not necessarily coincide. Means of how to obtain good distribution on a number of sedimentation units, good inlets and outlets, and especially desired properties of stability and turbulence in the basins are suggested. Because in high rated basins the sludge increase is rapid, the sludge problem is discussed in relation to the quality of the sludge. Some types of basins for different kind of liquids and sediments are described. From author's summary

3947. Dietze, H. D., Determination of size distribution of spheres in solid bodies from the intersection circles in a plane intersection (in German), *Tech. Mitt. Krupp* **13,** 3, 51–55, July 1955.

Spheres are assumed to be randomly distributed. This is a special case of an old problem known in biometry as the corpuscle problem, which seems to have been first solved by S. D. Wicksell [*Biometrika*, 1925 and 1926]. Present author restates some previously known results and discusses the numerical analysis.

N. G. Blomqvist, Sweden

Geophysics, Meteorology, Oceanography

(See also Revs. 3858, 3905, 3939)

3948. Priestley, C. H. B., and Ball, F. K., Continuous convection from an isolated source of heat, *Quart. J. roy. Meteor. Soc.* **81,** 348, 144–157, Apr. 1955.

Using dimensional analysis and similarity arguments, authors arrive at description of the distribution of temperature, vertical velocity, and, by extension, concentration of pollutant, above a heat source in an otherwise calm atmosphere. The results are

a generalization of results by previous investigators [cf. Batchelor, title source, **80,** 345, 339–359, July 1954, see AMR **8,** Rev. 507]. Experimental data quoted by authors confirm the general form of solution but show the predicted values of temperature disturbance of atmosphere to be too high by factor of about two; authors suggest several explanations for this, but it is reviewer's opinion that radiative cooling of heated column of air may be the predominant factor, this factor not being included in authors' treatment. Allowance is made for lateral inflow into ascending column, but no treatment of the often observed tangential flow (rotating columns, dust-devils, etc.) is suggested. Results should be useful in predicting behavior of discharge from chimneys into calm atmosphere. F. I. Badgley, USA

3949. **Priestley, C. H. B., Free and forced convection in the atmosphere near the ground,** *Quart. J. roy. meteor. Soc.* **81,** 348, 139–143, Apr. 1955.

From dimensional arguments and using data from Swinbank's experiments [*Tech. Pap.* no. 2, Commonwealth scient. and indust. Res. Org., Australia, 1955], author discriminates between conditions leading to free (buoyant) convection or to forced (wind-driven) convection in the atmosphere near the surface of the earth. Consideration is limited to unstable thermal stratification of the atmosphere (superadiabatic lapse rates). The interesting implication of author's results is that the transition from free to forced convection is a sharp one and that, under a given set of conditions, one or the other will prevail so that the meteorologist or engineer need not worry about both in a single problem but can concentrate on the one dominant process.

F. I. Badgley, USA

3950. **Zierep, J., Forces and moments on a drop in a horizontal air current with vertical shear** (in German), *Z. Flugwiss.* **3,** 22–25, Jan. 1955.

Differential equations describing incompressible laminar flow across a cylinder and past a sphere are studied and then linearized corresponding to the case of small obstacles. On this basis, author deduces simple expressions for vertical forces experienced by obstacles in horizontal wind fields with vertical shear. Sample result for lift K on a sphere of radius a in a wind of horizontal speed U and vertical shear U' (increasing upwards) in a medium of density ρ is

$$K = \frac{16}{3}\pi\rho a^3 U\, U'$$

In meteorological applications, forces of this kind are generally negligible. For liquid droplets, K is several orders smaller than particle weight. Author points out, however, possible applications in aviation, though the approximation made would probably be less permissible there. W. Hitschfeld, Canada

3951. **Kubota, S., Numerical prediction by the quasi-double Fourier series,** *Pap. Meteor. Geophys.* **5,** 3, 144–152, Sept. 1954.

A spectral analysis of the contour field over most of the northern hemisphere is made for a single day in winter, including wave numbers 1 through 9. Spectral distribution of kinetic energy is computed (maxima at wave numbers three and six). Interaction of components (i.e., nonlinear term) in advection of vorticity is computed and a forecast of each component made. Since contour charts are not reproduced and there is no discussion of methods used in computation, and forecast results are not encouraging, it is difficult to assess accuracy of spectral distributions. M. Wurtele, USA

3952. **Sandauer, J., Gust loads on an airplane wing** (in Polish), *Techn. Lotn.* **9,** 6, 160–167, 1954.

Structure of a gust is examined, the maximum normal acceleration of an airplane occurring at the end of transition zone. Actual gust is replaced either by an equivalent sharp one with no transition zone, or by that with linear vertical speed distribution. An analysis of load is carried out for steady and unsteady flow; influence of the angle σ between the aircraft velocity and that of gust on the normal acceleration has shown the maximum acceleration corresponds to $\sigma \cong 65 - 75°$. Wagner's equation for a sudden lift increase and Küssner's method for a continuous lift increase are used. The effect on the pitching moment and the influence of wing elasticity are investigated; corrections for a gust-load factor are computed. Elasticity influence attains its maximum if the time of attaining maximum load is $t = 3\pi/2\omega$ sec. Criteria limiting the application of gust-load factors are given.

P. Bielkowicz, USA

Lubrication; Bearings; Wear

(See also Revs. 3613, 3670, 3787)

3953. **Charron, F., Comparison of shock resistance of lubricating films** (in French), *Publ. sci. tech. Min. Air. France,* no. 298, 1–18, 1955.

Experiments on the load-carrying capacity of a plain journal bearing have been carried out using simple apparatus in which load could be suddenly applied. Breakdown of the oil film was assessed by the time taken for the friction to rise to a predetermined value characteristic of boundary lubrication following sudden applications of load. Tests at steady loads are also reported. A series of lubricants have been investigated including some with widely different ratios of viscosity at 321 atmospheres to the value at atmospheric pressure. No correlation is found between the tendency of the viscosity of a lubricant to increase with pressure and its ability to withstand constant or suddenly applied loads on a journal bearing.

The study is a valuable one, but reviewer considers that some refinement of instrumentation and an extension of the range of variables so as to permit nondimensional representation of results would yield more valuable information.

F. T. Barwell, Scotland

3954. **Kettleborough, C. F., A simple electrical network analogy for the solution of the stepped thrust bearing,** *Austral. J. appl. Sci.* **6,** 1, 32–37, Mar. 1955.

Author simplifies his analysis of stepped thrust bearing [AMR **7,** Revs. 1343, 3436] by substituting an electric analogy for relaxation solution initially used. Analogy is between Reynolds equation for two-dimensional pressure distribution over slider and equation for potential distribution at nodal points of an electric resistance network having equal resistance per mesh width in both coordinate directions.

Potential measured at nodal points equals corresponding lubricant pressure if (1) boundary conditions are same, (2) resistance values on inlet and outlet sides of step equal viscosity divided by cube of corresponding film thickness, and (3) continuity condition at step is preserved in electrical network. Last condition is satisfied by feeding a current equal to ratio of film thicknesses minus one, multiplied by mesh width ratio and divided by electrical resistance on outlet side of step into network at nodel points intersected by step. Reviewer notes relation was obtained using finite difference expressions for voltage derivatives involving only first differences, whereas continuity equation for relaxation solution also included second differences. Effect on results appears to be negligible.

Pressures determined from measured voltages agree well with those obtained by relaxation solution. Values of load-carrying capacity differ by less than 2%, difference being due primarily to normal scatter of resistance values.

Author concludes that, once electrical circuit is available, results can be obtained in a far shorter time than required by relaxation solution. Effects of step shape are easily studied by changing resistance values along the step, resistance on either side being proportional to distance from adjacent nodal point. Film thickness ratios can be varied by changing resistance values on one side of step.

Reviewer anticipates further work by author on subject, particularly actual tests of bearings designed on basis of these analyses. These would show influence of such factors as viscosity variation over slider, neglected in both relaxation and analogy solutions.

H. E. Brandmaier, USA

3955. Abramovitz, S., Theory for a slider bearing with a convex pad surface; side flow neglected, *J. Franklin Inst.*, **259,** 3, 221–233, Mar. 1955.

The cross section of the boundary of the curved pad is assumed to be a portion of a circle which, for small height of the crown segment, can well be approximated by a parabola. If the pad inclination is small, the film thickness can be calculated by subtraction of the crown-segment height from the distance between the chord of the crown segment and the flat surface on which the pad slides. The resulting equation representing the dependence of the film thickness on the distance from the inlet contains two parameters, the ratio between the inlet and outlet film thickness $a = h_1/h_2$ characterizing the pad inclination, and the ratio between the maximum height of the crown segment and the outlet film thickness $\Phi = H_c/h_2$ marking the pad shape.

Author inserts this film thickness function into the Reynolds equation and solves it, paying regard to the boundary conditions so that the pressure must vanish at inlet and outlet. In this manner he calculates the pressure distribution, the load, the friction, and the center of pressure in dependence upon a and Φ. For representing the results, a dimensionless plotting is chosen. For forming the dimensionless expressions, viscosity, velocity, length and breadth of the pad, and either outlet film thickness or minimum film thickness are used. The support factor is defined by the ratio of the coordinate of the pressure center and the pad length. It is interesting that, for all support factors from 0.5 to 0.6, the maximum load capacity was at a crown to minimum film-thickness ratio of 0.35. A curve of the dimensionless load versus the support factor for this optimum crown ratio shows that the optimum support factor has a value of 0.55. The use of this optimal support factor and crown ratio gives a 10% increase in load capacity as compared to a flat pad located at its optimum pivot point. The theory for a flat-surfaced pad pivoted at the pad center yields zero load capacity in contrast to the theory discussed here for the curved pad slider. Because central pivoted pads must be used in bearings which are capable of rotating in both directions, the curved pad slider is of great importance.

According to the fact that the minimum film thickness does not lie at outlet for high-crown and low-inclination conditions, sometimes pressure distributions with negative pressures are found. In these cases the obtained results are invalid, for it is not admissible to use the above-mentioned boundary conditions because the fluid cavitates.

U. Rost, Germany

3956. Robinson, G. M., Bearing material evaluation for railroad use, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-110, 12 pp.

Paper describes in detail a machine built in connection with a study for the Association of American Railroads to assist in the evaluation of bearing materials for railroad freight-car journal bearings. Typical coefficient of friction vs. time and bearing temperatures vs. time curves are discussed for both phases of the evaluation program: (a) when the material is being run in under a copious supply of oil, and (b) when the bearing is running with an inadequate supply. Curves of five different materials are presented, and different performance characteristics are discussed. The possibility of using this machine to evaluate the performance of special lubricants is pointed out.

From author's summary

3957. Bisson, E. E., Johnson, R. L., Swikert, M. A., and Godfrey, D., Friction, wear, and surface damage of metals as affected by solid surface films, *NACA TN* 3444, 60 pp., May 1955.

A summation is presented of NACA results obtained from friction and wear investigations from 1946 to 1954. The results are consistent with theoretical predictions that solid surface films of low shear strength can serve to reduce both friction and surface damage. Metallic oxides can have very marked effects. Wear studies show that the ability of materials to form surface films is an important factor in wear. Solid lubricants (MoS_2 and graphite) are beneficial under severe operating conditions, including temperatures approaching 1000 F; both materials are, however, subject to oxidation at these temperatures.

From authors' summary

Marine Engineering Problems

(See also Revs. 3650, 3779, 3797)

3958. Volpich, H., and Bridge, I. C., Paddle wheels. Part I, Preliminary model experiments, *Trans. Instn. Engrs. Shipb. Scot.* **98,** parts 5,6; 327–372, 373–380, 1954/1955.

This purely experimental investigation gives thrust, revolutions, and speed of advance—represented in quasi-dimensionless form—for two geometrically similar paddle-wheel models. Open-water tests are carried out with an immersion of 0.15 × diam over floats for radial wheels and feathering wheels, too. The latter are superior in thrust and efficiency. Scale effect between both the wheels of 3.4 and 1.7-ft diam is stated without full explanation. The differences in efficiency amount to 10% in some points only (with different signs). There is a long discussion added to the paper.

H. Thieme, Germany

3959. Rödström, R., Resistance experiments with divided ship models, *Medd. SkeppsProvAnst. Göteborg* no. 30, 13 pp., 1954.

3960. Doust, D. J., Some aspects of and recent developments in launching, *European Shipbldg.* **4,** 3, 54–58, 1955.

3961. Kinoshita, M., and Okada, S., On the twisting moment acting upon a ship's rudder-stock, *Inter. Shipbldg. Progr.* **2,** 9, 231–240, 1955.

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